IRON AND STEEL ENGINEER

J. F. KELLY, Editor

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COMING MEETING AND PAPERS

PHILADELPHIA DISTRICT SECTION

INSPECTION TRIP—Bethlehem Steel Company, Sparrows Point, Md.

Friday, May 14th, 1926

By-Product Coke Plant, Blast Furnace Department, Power Plants, Bessemer Department, Open Hearth Department, Rolling Mills, Sheet and Tin Plants—One of the Most Modern Steel Plants in the United States Today.

Members of all district sections and friends of the Association of Iron and Steel Electrical Engineers are invited to attend this trip.

Train leaves Union Station, Baltimore, 8:10 A. M., arriving at Sparrows Point at 8:45 A. M. In case you miss the train, take the street cars and report at the Electrical Department, where guides will be glad to take care of you. Luncheon will be served at the new sheet and tin plate restaurant. Later, the entire body will proceed by trolley to the Maryland Swimming Club, where dinner will be served. General Headquarters, the Southern Hotel, Baltimore, Md.

General Chairman, H. S. Boone, Plant Engr. Shoemaker Bridge Company, Pottstown, Pa.
General Secretary, Linn O. Morrow, Schaff Bldg., Philadelphia, Pa.

PITTSBURGH DISTRICT SECTION

Last Meeting of the Year

Saturday, May 8th, 1926

"MAINTENANCE—STEAM TURBINES."

By A. L. Penniman, Supt. Steam Stations, Consolidated Gas Electric Light & Power Company of Baltimore, Baltimore, Md.

Meeting Will Be Held At the Lincoln Club of Pittsburgh.
222 Craft Avenue, Pittsburgh, Pa.

PROGRAM

6:30 P. M.—HOME COOKED DINNER—6:30 P. M.
7:30 P. M.—TECHNICAL SESSION—7:30 P. M.

CLEVELAND DISTRICT SECTION

OHIO ENGINEERING SAFETY CONFERENCE

Wednesday, May 5th, 1926

Cleveland, Ohio

Under the auspices of the

Association of Iron and Steel Electrical Engineers
(Cleveland District Section)
Society of Ohio Safety Engineers
American Society of Safety Engineers
Engineering and Metal Section, National Safety Council
AND THE
Cleveland Safety Council

Winton Hotel Ball Room **Morning—Afternoon—Evening**

MORNING SESSION

Winton Hotel Ball Room 10 A. M. to 12:30 P. M.

1. **"The Safe Operation of Electric Overhead Traveling Cranes."**
   - (a) **"Employing and Training Crane Operators and Floor Men."**
   - (b) **"Electrical and Mechanical Protection."**
2. **"Good Order—An Essential for Safety."**
3. **"Gas and Electric Welding."**

AFTERNOON SESSION

Winton Hotel Ball Room 2 P. M. to 4:30 P. M.

1. **"Proper Handling of Fuses Including Installation and Maintenance of Electric Safety Switches."**
2. **"The Personal Problems in Accident Prevention."**
3. **"Which Comes First—Production or Safety?"**

EVENING DINNER MEETING

Rainbow Room, Winton Hotel

Subject: "Maintaining Interest in Safety."

ENTERTAINMENT

Dinner Tickets, $2.00 each; may be obtained from the Cleveland Safety Council, 301 Chamber of Commerce Bldg., Carl L. Smith, Managing Director. Phones, Main 3300—Main 60.

SPONSOR COMMITTEE

Roy S. Sawdey, Chairman of Committee, Association of Iron and Steel Electrical Engineers.
J. M. Woltz, President, Society Ohio Safety Engineers.
W. Dean Keefer, Secretary, American Society of Safety Engineers.
T. P. Kearns, Superintendent of Safety and Hygiene, Industrial Commission of Ohio.
Chas. B. Scott, President, National Safety Council.
J. O. House, Vice President, Cleveland Safety Council.
George H. Schaeffer, President, Association of Iron and Steel Electrical Engineers.

EDITORIALS

IRON AND STEEL EXPOSITION

and

ANNUAL CONVENTION

June 7th to 10th, Inclusive

Hotel Sherman, Chicago, Ill.

PAPERS

Safety Code—Rules for the Safe Operations of Electric Overhead Traveling Cranes.

Electric Transportation—Yards, Mills and Factories.

By

W. P. Potter, Engr. Railway Department, General Electric Company.

Harold J. Payne, Electrical Industrial Truck Department, The Society for Electrical Development.

O. H. Needham, Engr. Dept., Westinghouse Electric & Mfg. Company.

D. C. Hershberger, Engr. Railway Section, Westinghouse Electric & Mfg. Company.

Refractories for Steel Mills.

By

M. S. Booze, Senior Fellow, Mellon Institute, Pittsburgh, Pa.

W. J. Harper, Combustion Engr., Donner Steel Company.

M. J. Conway, Combustion Engr., Wheeling Steel Corporation.

E. W. Trexler, Combustion Engr., Bethelehem Steel Company.

W. H. Kelly, Refractory Engr., Bethlehem Steel Company.

Electric Heat in the Iron and Steel Industry.

By W. P. Chandler, Spec. Engr., Carnegie Steel Company.

Standardized Mill Type Motors.

By A. C. Cummins, Elect. Supt., Carnegie Steel Company.

Additions to Rolling Mills at Steubenville Plant, Wheeling Steel Corp.

Description of Auxiliaries, Boiler Plant Equipment, Gas Producers, Soaking Pits.

Description of the 35" Blooming Mill.

Description of the 19" Continuous Sheet Bar Mill.

Detailed Description of Nordberg Reversing Uniflow Engine and Operating Control.

Results of Tests of the Nordberg Engine Giving Steam Consumption Per Ton of Steel Rolled. By M. J. Conway, Combustion Engr., Wheeling Steel Corp., Steubenville, Ohio.

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Strip Steel And Mills For Its Production

By NOBLE JONES*

General

STRIP steel was primarily considered as any flat steel less than 6 in. or 8 in. wide and under ⅛ in. in thickness, it being rolled in mills having rolls 8 in. to 12 in. diameter. This strip steel included hoop and cotton ties.

Today strip includes any flat section from ⅜ in. to 24 in. in width and from 0.005 in. to ½ in. thick. This classification also includes the so-called band and hoop steel sizes. Band steel is usually considered as steel from No. 12 B.W.G. to 3/16 in. thick in any width. Hoop steel is usually considered as steel No. 13 B.W.G. and less in thickness, in any width under 6 in.

Some producers are at variance with the above, they classify anything under 8⅝ in. in width as hoop; the wider material being classed as bands. Flat wire is also a name sometimes given to strip.

In this article all will be considered as strip steel. Wherever gauge is mentioned Birmingham Wire Gauge is intended, as it is the one universally used for strip steel.

Other classifications for strip steel are hot strip and cold strip, having reference to the temperature at which the steel is rolled. Hot strip steel is that steel which is heated to a proper temperature in a suitable furnace and rolled on a hot strip mill. The temperature may be about 2300 deg. F. for soft steel and lower for high carbon steel. Cold strip steel is that steel which is produced by re-rolling the hot strip when cold on a mill designed for that purpose to give greater accuracy of gauge, better finish, and a better control of the physical properties of such steel.

Uses of Strip Steel

Strip steel has a variety of uses and since the advent of the more modern mills it has invaded the territory once predominated by the sheet steel market. Fortunately, however, sheet steel has found greater uses and therefore this invasion has had little or no effect. Not only has strip steel entered the sheet steel field, but it has also taken the places of many of the cast metal parts because of its strength, lightness, ease of manufacture, pleasing appearance and the resulting less cost. Cast iron, steel and brass, as well as malleable iron, have been replaced in many cases by such use of strip steel.

Strip steel is used in various automobile parts, such as side frames, step hangers, brackets, brake bands, lamps, instrument panels, fenders, rims, hardware, etc. It is used in door hinges, metal molding, metal lumber, stove parts, metal furniture, cutlery, tubing, bicycles, etc. It may be truly said that it is used "from the cradle to the grave," for it goes into baby carriages and burial caskets, and there is hardly a day that the average person does not make use of strip steel in some form or other in his daily work or habits. In August 2, 1923 issue, "The Iron Trade Review" cited over 300 uses for strip steel. The probable production of strip steel is about 2,000,000 tons per year.

*General Manager, West Leechburg Steel Co., West Leechburg, Pa.

Metallurgical and Physical Requirements

The chemical content and the kind of strip steel depends upon the uses to which the steel is to be put. For deep drawing work, low carbon, basic open hearth steel is very desirable. Such steel may have an analysis of 0.08/0.12 carbon, 0.35/0.50 manganese, under 0.040 sulphur and under 0.040 phosphorus. Where slight drawing and bending is necessary and extra strength is needed without too heavy section, as in automobile frames, the steel may range from 0.18/0.30 carbon. For making parts subject to abrasion or great wear and where a greater degree of toughness is desired, as in chains, the carbon may be 0.25/0.30 and the manganese 0.50/0.56. Usually steel for this purpose is heat treated after forming for final use

Hoop steel is made from acid and basic as well as Bessemer steel. Very little acid steel is used today for hoop. Steel for this purpose has to be stiff enough without stretching to any great extent when formed into hoops and placed upon barrels. Carbon content for this purpose may vary from 0.15/0.30, depending somewhat upon the remaining content and kind of steel.

Acid steel (say it reverently since the Eighteenth Amendment), was very good for working hoop steel. It finished with a smooth surface and left no black mark on the whisky barrel in driving the hoop down over the staves. Basic steel very often left such marks. The coopers objected to this marking of the barrel. Acid steel analysis was 0.15/0.30 carbon, 0.35/0.45 manganese, 0.075/0.120 phosphorus, and under 0.075 sulphur.

Strip mills are of many sizes and types, depending upon conditions and material to be rolled. Strip steel is rolled from slabs or billets, the sizes of which depend upon the finished widths desired. The wider the strip wanted the wider is the slab used. As strip cools very rapidly, it is necessary that it be rolled as quickly as possible in order to obtain thin gauges. The types of mills vary from the old hand-operated Belgian style to the very modern continuous machine-operated type. The sizes of mills vary from 6 in. to 20 in. diameter rolls in the finishing stands. The roughing rolls, whether of three high, universal or continuous type of mill range from 8 in. to 24 in. diameter, generally.

Hand-Operated Mills

In Fig. 1 is a layout of a Belgian type strip mill. This is of the older type; the steel is passed forward and back through the various passes in the first two or three stands, until it is light enough to bend around, at which time the steel is looped from one pass to another. This mill is operated by hand, no machinery being used to convey the metal from one pass to another. Even the furnaces are hand charged and discharged.

A mill of this kind naturally requires a great number of men and most of them have to be

skilled in the handling of hot steel with tongs, and the setting of guides, etc. In addition to this, the work is hard and the men have to be able to withstand the heat encountered owing to the closeness of the hot steel with which they have to work. With this type of mill the first cost is low; also the overhead. It has the advantage of permitting of quick adjustments for small orders and may be termed a strictly jobbing mill. On account of hand operation, the sizes of billets or finished strip may vary in weight from 75 lbs. to 300 lbs. each, depending upon widths and gauges.

Semi-Continuous Mills

Fig. 2 illustrates an advanced step from the mill shown in Fig. 1. This is a semi-continuous mill, where four flat rolls and two sets of vertical rolls are in line. The last set is one of a train of

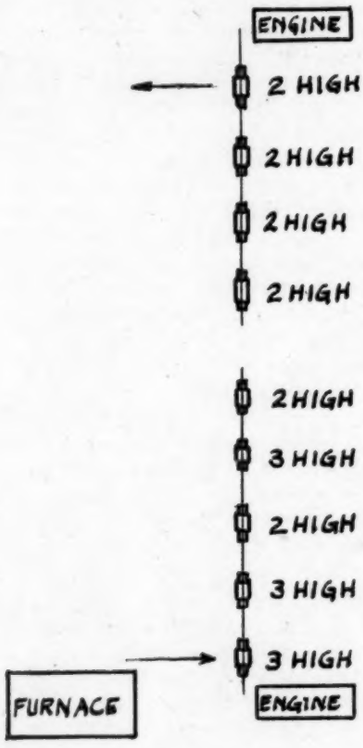


FIG. 1.

five stands of flat rolls. In this type of mill the steel is handled mechanically except at the finishing stand, where hand labor is employed to bend the strip around or to enter it between the rolls. One or two continuous furnaces heat the steel for a mill of this kind. The steel is charged and discharged by mechanical means. This type of mill invariably uses all flat rolls except those which are for edging purposes, which are in this case vertical grooved rolls. This type of mill has the advantage of higher rolling speeds, heavier finished weight of strips, greater production, smaller operating crews; it also permits to a very great extent the easy and quick adjustments required of a jobbing mill. This mill may be classed as one of moderate, initial cost.

Fig. 3 shows another mill of the semi-continuous type with the horizontal edging rolls in the first and fourth passes, whereas the sixth pass is of the vertical edging roll type. Both this mill and the one shown in Fig. 2 roll slabs into strips. In the mill in Fig. 3 horizontal edging rolls are

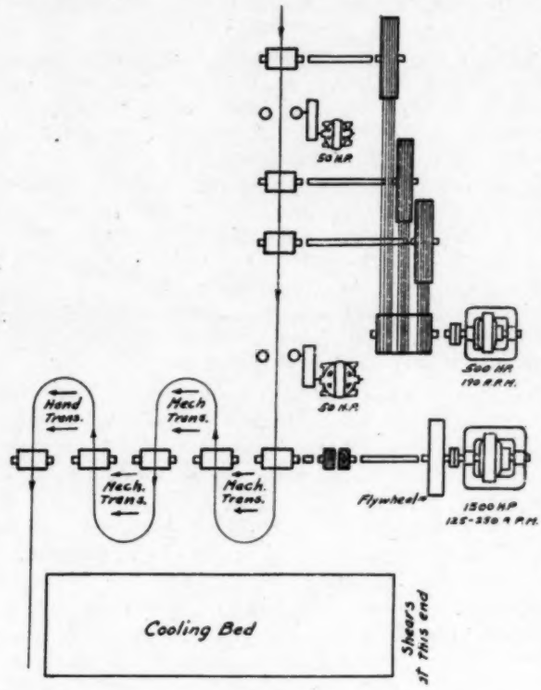


FIG. 2.

used so as to get rid of as much scale as possible. This edge rolling causes a great amount of the scale to become loosened and therefore drop while the slab is on edge. The working of more stands in continuous formation permits of rolling the steel

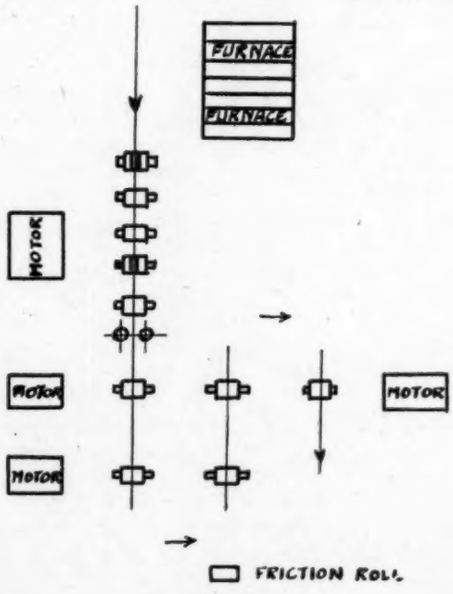


FIG. 3.

while hotter and therefore is better able to produce lighter gauges when required. This mill is of a more expensive type, but capable of great tonnage with moderate labor cost.

Fig. 4 is another modification of a semi-continuous mill, in which repeaters or looping devices are used to conserve both labor and heat between roll passes. In a mill of this kind a duo stand of rolls is used. This type of mill is a large producer.

Fig. 5 is still another type in which a universal reversing set of rolls is used. A mill of this kind

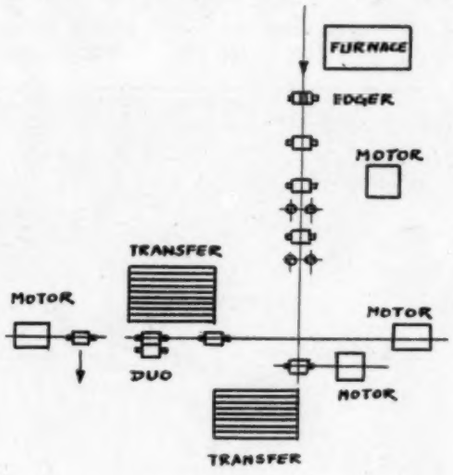


FIG. 4.

will produce large tonnages of heavy strips and has a moderate initial cost, as well as small operating crews.

Continuous Mill

Fig. 6 is a mill of the straight, continuous type. The steel is in several passes at the same time. It may be readily seen that predetermined drafts

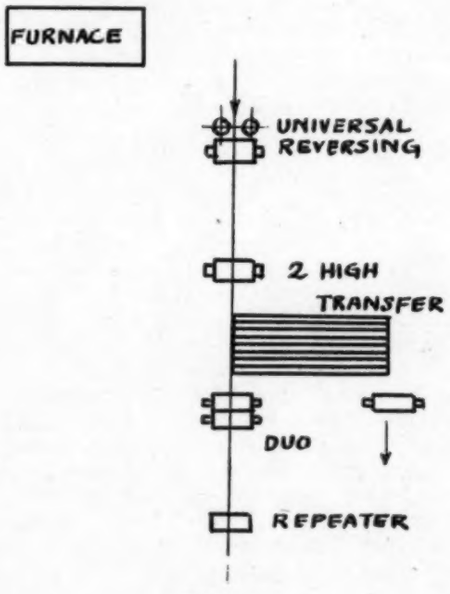


FIG. 5.

and speeds are essential to prevent looping or stretching between passes. Speed, high tonnage and small crews are obtained with a mill of this type. Such a mill is capable of producing light gauges because the steel is always hot, but this mill cannot be considered a jobbing mill because of the work and set-up required for changing orders. Mills of this kind are in operation having delivery speeds of 1,000 to 2,500 feet per minute.

Modified Continuous Mill

Fig. 7 is a modification of a continuous mill. This has all roughing stands continuous and all finishing stands continuous with mechanical transfer between. This mill was designed to roll wide strips of light gauges and at the same time have the ease of adjustments to make fairly rapid changes of orders. Furthermore, it permits of rolling steel at a suitable temperature for the work required and permits of a large production.

As with many of the continuous mills of modern times, this mill has direct current adjustable speed motors on those passes in which steel is rolled light in gauge and at high speed of de-

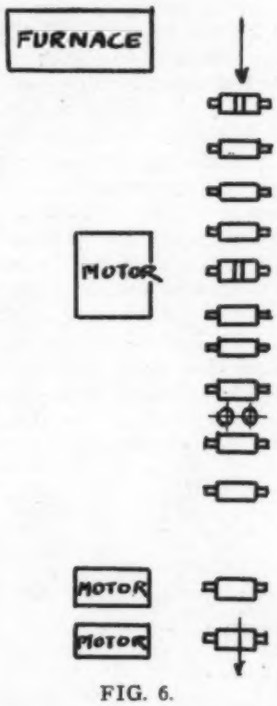


FIG. 6.

livery. This drive is used in order to make quick changes of speed to avoid excessive looping or stretching of steel between passes. The roughing stands, which are usually of low speed, are geared to a single power driven unit, as shown in Fig. 7. This is a constant speed motor with no provision made for speed change, as such adjustment is not required. However, it is not only essential to have adjustable speed motors on wide strip mill finishing stands, but it is also essential that speed regulation be practically constant between no-load and full load, otherwise it is a difficult task for any operator to keep from excessive looping or stretching of steel, for one motor may be carrying full load and the one next to it quarter load.

Steam Engines Replaced by Motors

Years ago most of the older mills were driven by steam engines, today many of these have been replaced by electric motors; practically all of the modern mills are motor driven. Where constant speed is desired, alternating current motors are

used, but where adjustable speed is essential the modern installations are of direct current motors because of simplicity, ease and range of operation. The electric motors have proven superiority over steam engines for strip mills because of the ease of operation and lower operating cost. In fact, if it had not been for the adjustable speed electric motor, high-speed wide strip mills would not have been successful. It is common opinion that by means of electric motors loads can be equally distributed because of meter indications. This is true to a certain extent. There are, however, times when roll draft determines the condition of strip upon delivery. Too great or too light a draft may be a detriment in flat strip.

Method of Rolling

In order to procure flat strip, beside giving proper draft, the last finishing pass in any mill is usually driven by separate power whether it be in an old or modern type mill. This is because any distortion or chatter due to the action of the mill when connected with another would very likely cause a strip to deliver wavy and not flat. Only the bottom roll is driven, whereas the top roll rotates by friction with the bottom roll or with the strip with which it is in contact. The top roll is sometimes arranged so as to have a slip clutch or other device to keep it from stopping when the mill is in operation; if it would stop rotating both roll and strip would be marked or destroyed.

The rolls used in strip mills are both chilled iron and steel. The chilled iron is used on finishing passes and the steel rolls on roughing and edging passes. The chilled iron gives less trouble

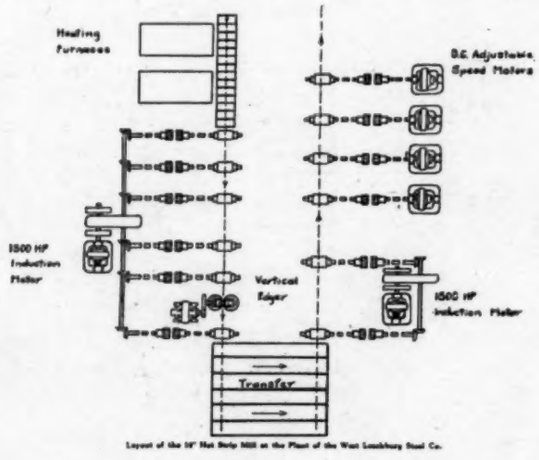


FIG. 7.

and a better finihed strip. Mill housings are mainly cast iron, but in a few of the mills cast steel is used. Roll bearings are mostly bronze castings and some mills are using bronze castings with babbitt inserts. Roll grease is used as a lubricant. Reducing gearing and equalizing mill pinions in modern mills are of steel and cut herringbone teeth running in a bath of oil.

Heating Furnaces

Furnaces used for heating steel billets are of hand and continuous types. Fuel used is either natural or producer gas, oil or coal. The hand type furnace is usually of the regenerative type with a sand bottom. The objection to this furnace is the amount of labor necessary and the small weight of billet which has to be used on account of the manual labor involved. The continuous furnace is of the recuperative type. Steel is charged by means of a crane and a furnace pusher, which is a mechanical contrivance operated by electric motor or steam cylinder.

The pusher shoves the steel along water-cooled skid pipes which are in the furnace and which

FIG. 8.

extend the full length of the furnace or practically so. In many cases the skids extend to a hot brick or sand bottom, from three to five feet long, in the discharge end of the furnace. The purpose of this bottom is to allow the heat of the billet or slab to become uniform, for where it rests on the skid pipes it very often has dark, cold spots. These have a tendency to create varying thickness in the finished strip. Hot steel is discharged from the continuous furnace by gravity at the mill end of the furnace, or by mechanical means through the side of the furnace near the mill end. The former method is used on large slabs or heavy billets, while the latter method is used for small slabs or small billets.

The furnace for large slabs usually has a width from eleven to fifteen feet, whereas, for small slabs or small billets, the width is made to accommodate lengths up to thirty feet. In the latter type of furnace the water-cooled skids are dispensed with and a water-cooled casting of short length is used on the charging end of the furnace. Charging this type of furnace is done by pinch rolls, which enter the billet at the side of the furnace, near the charging end. Mechanically charging slabs or billets in either type of furnace thereby causing the pusher to move the bed of billets in the furnace causes the hot billets either to discharge or to be in position for discharge, prior to the rolling operation.

Shears are placed between the furnace discharge and the first mill pass. These may be of the flying shear type to cut the billet or slab while in motion, or of the plunger shear type, which cuts the piece while at rest. The former is used on small billets or slabs and the latter on large billets or slabs to give the desired finished lengths.

Scale which forms on hot steel is removed by blowing steam, water or air at high pressure upon the steel as it goes through the mill at various passes. Steel brushes and steel scrapers are also used.

Auxiliary Apparatus

The auxiliary apparatus about a modern strip mill consists of roller tables, reels, cooling beds, and finishing shears. Roller tables are used to convey steel between rolls and also when finished. Reels are used to coil hot steel as rolled from the

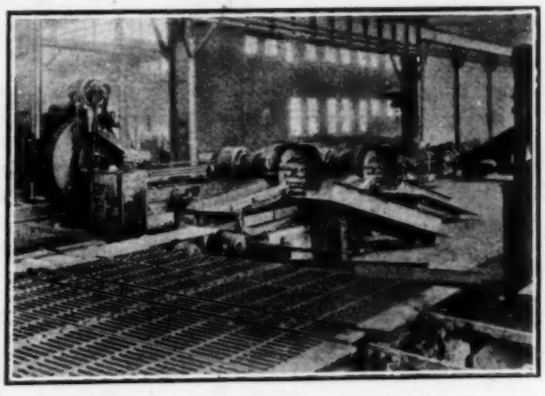


FIG. 9.

mill. If the steel is to be cut it is conveyed on a roller table to a cooling bed, where it is allowed to cool enough to handle. It is then cut to the desired length by shears, usually of the plunger type.

On wide strip mills the cooling beds are mechanical, driven by electric motors. With some mills of the smaller, semi-continuous type, finished strip is handled by manual labor, and laid on the cooling bed by hand labor with tongs and then in the same manner dragged to shears for cutting to the lengths desired.

Some continuous mills do not use a hot bed at all, but coil all strips and cut later by passing steel through leveling rolls and shears. This method has its advantages and disadvantages, depending upon what is desired to be made and the cost of operation.

Fig. 8 is a view of a strip mill showing two continuous furnaces of the gravity discharge type. At the right is shown the cooling bed, with two finishing shears in the distance.

Fig. 9 shows reels of pin type used for coiling hot steel at the end of the cooling bed.

Fig. 10 is one of the adjustable speed, direct current motors used on the finishing pass of the mill shown in Fig. 8.

Sizes of Rolls and Motors

The sizes of rolls and roll motors used is, of course, dependent upon the size the material is finished, as well as the speed and temperature of the steel during rolling. Tests have been made on various mills, including all auxiliaries, which indicate the power consumption varies from 80 to 140 kw-hrs. per ton of steel finished. For wide, light strip mills doing jobbing work at a moderate speed, 115 to 125 kw-hrs. would be a good average.

The sizes of motors used on auxiliary apparatus are as follows:

Tables	20 to 60 Hp.
Furnace Pushers	20 to 40 Hp.
Transfers	20 to 40 Hp.
Reels	15 to 30 Hp.
Shears	20 to 40 Hp.
Vertical Rolls	50 to 100 Hp.

Description of Processes

Strip steel is furnished either in coils or cut in lengths; plain black, pickled, limed, oiled, soaped or galvanized.

The pickling process consists in dipping the coils or strips in a hot bath of dilute sulphuric acid until the scale is removed. This is done by placing the steel on specially constructed crates of acid-resisting material and by the use of a crane the crates and steel are lowered into the acid, which is contained in large tanks built of acid-resisting material. Steel is removed from the tanks and rinsed in water and given the final dipping in tanks containing lime soap, or oil. Coils of steel of heavy gauge are run through machines known as recoilers before pickling. The purpose being to make a spiral or loose coil, so that the acid may have free action on all surfaces.

Coils of moderate widths and gauges are very often run through a continuous pickling machine. This consists of shallow tanks containing various liquids in line so arranged that several strips of the steel pass through the desired tanks and are rewound on drums of multiple head power driven reels. Successive strips are drawn through by riveting, linking or welding ends of coils together, thus making the strip continuous. The ends which have been made

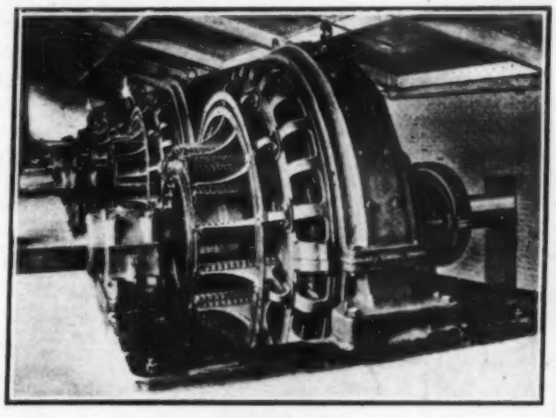


FIG. 10.

unfit for commercial purposes, are cut off as they come to the reel.

Galvanizing is done similarly except that a tank of hydrochloric acid solution is also used in conjunction with the sulphuric acid and water. After the steel leaves the hydrochloric tank it enters a hot zinc bath with mechanical contrivance for conveying it through onto multiple head reel. This is a continuous galvanizing process.

When accuracy of width is desired, the steel is run through a slitter, which trims the edges of the strip. The slitter is a machine having rotary cutters. The work is done cold. Hot rolled strip is usually

furnished to the trade in coils, bundles or loose strips. The two former are banded with light, narrow strip steel, which is either twisted or folded to make a tight band.

The above covers, in a general way, the subject of hot strip mills and practices. The next consideration in strip mill apparatus and operation is the cold rolling of steel and mills for it.

Cold Rolling Steel

Very little has been written about cold rolled steel. It seems to be a very delicate subject, as each works has its own individual practices and operations regardless of what has been done or is being done in other plants. However, all are striving for one purpose, and that is to satisfy a very critical trade.

Strip steel is cold rolled by taking the hot rolled strip mill product and cold rolling it through a mill at a comparatively low speed. The purpose of cold rolling is to give accuracy of gauge and temper, as well as a highly polished product. The first cold rolling of strip steel was done in 1871. In 1916 there were approximately twenty cold rolling plants in the United States. Since then the number has increased very considerably.

Cold rolled steel is used very extensively in the automobile industry, and it, above all others, has greatly increased the use of cold rolled steel in the past few years. This steel is also used in many electrical appliances, such a irons, telephones, etc., also in typewriters, adding machines, tableware, etc.

A great percentage of the steel is cold rolled to a finished gauge which will range between 0.005 in. to 0.040 in. The width range is from a fractional part of an inch to 30 in. Any width over 24 in. is exceptional. Widths under 3 in. are often obtained by slitting wider strips into narrower ones.

A variety of tempers are made and the practice of producers is not standardized, but refers to that temper in working of soft or low carbon steel. Some makers prefer to call their tempers by numbers classified from 1 to 4. The Number 1 being a clean blanking steel of high tensile strength, permitting very little bending. Number 4 being dead soft steel for deep drawing. Other firms desire to use the terms Full, Half, Quarter Hard and Dead Soft Steel, depending upon the degree of hardness and purpose for which it is intended. Hard steel is for flat work, Half Hard steel will bend at a sharp right angle. Quarter Hard steel will bend upon itself across the grain and fairly well with the grain. Dead Soft steel will bend either way; it is used for deep drawing. The tensile strengths are as follows:

Full Hard Steel	85,000 to 140,000 lbs.
Half Hard Steel	80,000 to 85,000 lbs.
Quarter Hard Steel	50,000 to 60,000 lbs.
Dead Soft Steel	44,000 to 50,000 lbs.

The greater percentage of steel is made from low carbon basic open-hearth steel, but for special purposes high carbon and alloy steels are used.

If scale and dirt are permitted on the strip a bad surface will result. The steel must be free from scale, which is removed by pickling. The steel to be cold rolled is first pickled, as described in hot strip mill practice. It is then coated with lime or soap. The latter two tend to prevent rusting on exposure to the air for a short length of time, as well as to neutralize any acid remaining from imperfect rinsing. Some makers do not use either soap or lime, but merely rinse with water and work the steel before rusting can start.

Most cold rolled strip steel is rolled from coils of from 75 to 1000 pounds in weight. As with hot strip mills, the arrangement of rolls in cold rolling mills has been somewhat varied.

Types of Cold Rolling Mills

The original mills were either of single type or three or four two-high stands in train or Belgian style, driven by steam engines. Steel was passed over the tops of the housings from one stand to another, making the steel to deliver on one side of the mill from all passes until final reduction, when it was wound on reels. This was a very laborious arrangement, especially when rolling wide steel. About twenty-five years ago a continuous tandem mill was installed on which steel was rolled from one pass to another in succession. A reversing two-high mill may be used in cold rolling heavy flat lengths of steel.

There are various arrangements of rolls in mill housings. One arrangement consists of one small idle roll between two larger driven rolls; the large rolls drive the small roll by friction. Another arrangement has two small driven rolls with two backing-up rolls placed on the top roll and two on the bottom roll. These are so angularly placed as to give both driven rolls stiffening on top, bottom and sides.

Two high mills are those generally used. Formerly chilled iron rolls were used exclusively, but with the advancement of tempered steel rolls they are replacing the iron rolls. Greater work can be done in less time and delay with the steel rolls than with the iron rolls.

Roll bearings are usually bronze or bronze with babbitt inserts with grease lubrication. However, there are a few operators who use babbitt bearings with oil lubrication.

A few operators water cool rolls internally, but most do not, merely depend upon water playing upon the roll necks for cooling purposes. Speed and drafts have all to do with the heating of rolls and many of the greatest producing mills do not cool rolls internally.

The first rolling is the roughing or breaking-down operation and is usually done in modern practice on a mill layout as shown in Fig. 11. This is a mill having four two-high roughing stands in tandem formation with reel for winding up the finished strip.

The speed of the first stand may be from 40 to 100 feet per minute, depending upon the mill size and the material rolled. The finishing speed is from 80 to 200 feet per minute. The total reduction is usually not over 50 per cent in the four passes at one time because of hardness and reluctance of the metal to flow. Ordinarily four gauges reduction is made and occasionally three or five.

If more reduction is desired, the steel is annealed after which it is again reduced. Sometimes two or three anneals are necessary. Tempers other than full hard are determined by the amount of cold rolling after annealing. This rolling varies according to

gauge and stock, and is determined by previous practice and by the standardized tempers of the individual firm.

Very often steel is required to make deep drawing without being dead soft, in order that it will form smoothly without a wavy or uneven surface. In that case, the dead soft steel is given a slight additional rolling to give the desired stiffness. This is often referred to as skin or pinch rolling.

Hot rolled strip steel is invariably heavier to gauge in the center of the strip than at the edges

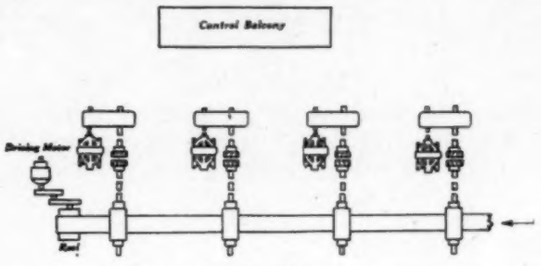


FIG. 11.

and sometimes one edge is heavier than the other. These inaccuracies, if excessive, cause trouble in the cold rolling. Heavy center causes buckling, and if the cold rolls are worn very much or are worn slightly concave then the edges of the strip become ruffled. These troubles are overcome by giving the rolls a crown from 0.003 in. to 0.008 in. on the diameter of 12 in. to 16 in. rolls, or by heating the center of the lower roll with gas, thus expanding it Sometimes the working of the rolls create internal heating, which gives the desired expansion; other times the expansion is too great, which causes additional trouble.

Some operators roll on the first pass or two with dry rolls and on the rest with a very light metal oil. Others use oil on all passes. However, all make large reductions in the first pass. This tends to iron out any imperfection which may have occurred in hot rolling The majority of operators prefer dry rolls as the most suitable for this purpose.

All through the various processes special precautions are taken to keep the steel clean, as dirt leaves its impression on the strip. Wipers of various kinds are used on the different stands. These press by mechanical means on the strip and tend to remove any dirt which may have accumulated. After coming through the roughing passes the steel is usually taken to the finishing mill, which has a light rolling draught merely to give high polish, accurate gauge, and flat surfaces to meet the commercial requirements. For one four-stand tandem set of roughing rolls, three single stands of finishing rolls are usually required.

The flat surfaces of the strip are not only obtained by careful rolling, but also by tension produced by the reel, which winds up the steel as it comes out of the mill. Many improvements have been made in reels. Today there are several reels on the market, which are designed for giving any tension desired. All, with one or two exceptions, utilize a mechanical friction clutch or a modification of it. Naturally, a lot of power is dissipated through this means, but the tension obtained is not very stable nor uniform.

Recently electrically controlled and operated reels have become perfected in which the disadvantages of the old type of reels have been removed, desired tension obtained and regulation secured. This has been a great asset in cold rolling of steel, especially in the wider sizes. Fig. 12 shows an electrically driven and controlled reel. Fig. 13 is a layout of this type of reel.

Fig. 14 is a layout of a strip mill.

Fig. 15 shows a tandem mill for cold rolling.

It is somewhat difficult to give figures on the power required to cold roll steel. What would obtain in one plant would not in another, as practices are so different. The following are sizes of motors in use on mills:

Size of mill—In.	Size of motor—Hp.
6	40
8	40 to 75
10	75 to 100
12	100 to 150
16	200 to 275
20	300

Practically all are direct current, adjustable speed motors. Ease of operation makes this type of motor most desirable even though not imperative. In most cases the speed ratio of 400 to 800 has been adopted for the motors. Constant speed motors may drive tandem mills if mechanical means are provided to take care of the looping between stands when required; the disadvantage remains, however, that the speeds are fixed for all materials which is not always desirable. Operation is also otherwise hampered.

Annealing Furnaces

There are many types and sizes of annealing furnaces used in connection with strip mills. The type most used is that which is charged and withdrawn at the same end of the furnace. Another type is the continuous furnace, in which steel is entered at one end and discharged at the other. The former usually

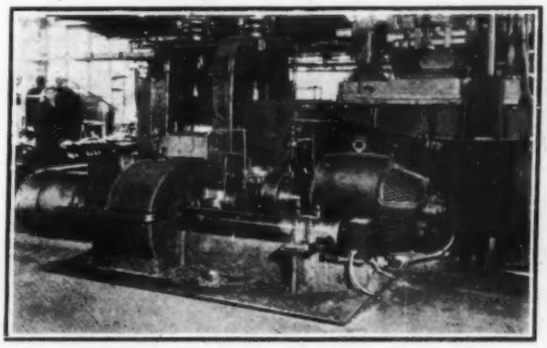


FIG. 12.

has capacity for one annealing box, whereas the latter type has capacity for four or more, depending upon the length of the furnace.

Lately an electric furnace has been in use in which the strip is drawn through the furnace and wound on a reel. This furnace is used for steel in coils, whereas the other types are for coils and cut length strips. Fuels for furnaces are coal, gas (natural and producer), oil and electricity. Steel to be annealed is placed on cast steel bottoms and covered with round or rectangular boxes, the edges of

which are sealed with sand or iron turnings to keep out the air.

Annealing boxes are charged and withdrawn by means of mechanical contrivances, electrically driven. These consist very often of pushers arranged on

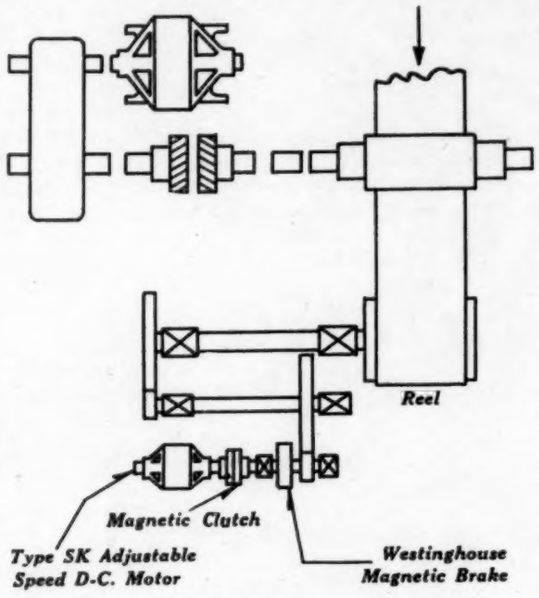


FIG. 13.

floor and overhead cranes, which are also used for loading the steel from the annealing box bottoms.

Soft steel is heated to a temperature between 1,150 to 1,350 dg. F. Great care is required to get the exact temperature. If underheated the annealing will be imperfect; if overheated the steel may stick

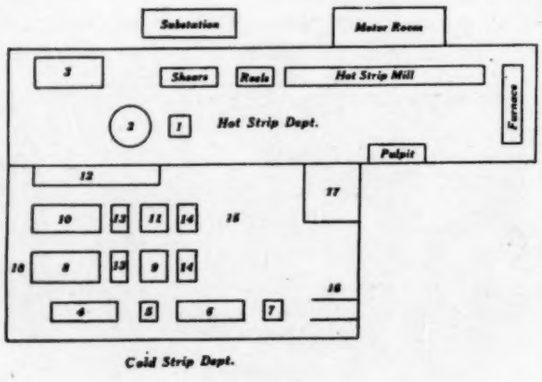


FIG. 14.

FIG 14—Combined Layout of Hot and Cold Roll Strip Departments

1. Recoiler
2. Pickler
3. Annealing Furnaces
4. Four Stand Tandem 10" Cold Rolled Strip Mill
5. Single 10" Finishing Stand
6. Four Stand Tandem 12" Mill
7. Single 12" Finishing Stand
8. Four Stand Tandem 20" Mill
9. Single 20" Finishing Stand
10. Four Stand Tandem 16" Mill
11. Single 16" Finishing Stand
12. Control Balcony With 20 Class 17150 Controllers
13. Strip Coilers
14. Electrically Driven Reels
15. Levelers, Automatic Straightening and Cut Off Machines, Etc.
16. Shipping Track
17. Office
18. Roll Lathes, Roll Storage, Etc.

or weld together; furthermore, crystallization may take place, which may make the steel unfit for purposes for which intended.

In order to have the steel keep a bright surface, it is essential that no oxidization takes place. This is the reason the annealing boxes are sealed from the outside air. Still another precaution is used; gas, natural or producer, is allowed to flow inside of the box. Some operators admit the gas while the box is in the furnace; others wait until the box is withdrawn from the furnace before using the gas. The box is allowed to stand several hours to cool before uncovering and unloading the steel. The whole procedure takes 2½ to 3 days.

Miscellaneous

Other auxiliary apparatus for cold rolling mills consist of the following:

Multiple roll coilers.
Cutting machines.
Levelers.
Slitters.
Edging machines.
Oiling machines.
Cleaning machines.
Special machines for special work.

The multiple roll coiler is used very often in conjunction with the mills. It is usually a five-roll machine; the rolls being staggered two on top and three

FIG. 15.

on the bottom, the top two being adjustable. Steel leaves the mill and passes between the two top rolls and the lower three rolls. Depending upon the pressure of the upper rolls is determined the size coils produced. The action is to give a set or shape in coil form to the steel, making what is known as a tight coil. A drum reel makes a loose coil. A multiple coiler is used in conditioning coils for annealing, as such coils are sometimes nested within one another and cannot be loose nor springy, as they would then be troublesome to cover with the boxes.

Cutting machines are a combination of leveling rolls and shears, which are used in conjunction to cut coiled steel into required lengths.

Levelers are machines with several rolls ranging in number from seven to nineteen, staggered and adjustable either in groups or singly. The top and bottom rolls are used to level or flatten the steel which has become distorted during operations.

Slitters are used about the same as in hot strip practice to procure more accuracy in width. These rotary cutters are arranged in gangs to slit two or more pieces from one wide strip. Extreme care must be used in setting up cutters to get clean edges

and very little burr. A set of rolls is sometimes used in conjunction with the slitter to roll and reduce the burr.

Edging machines are driven vertical rolls for producing smooth finish on the edges of the strips, as well as to give fair accuracy of width.

Oiling machines are those having fabric rolls which run in a bath of oil. Strip steel is passed between these rolls to give a protective coat of oil.

Cleaning or wiping machines are of many types; some with fabric rolls, brushes, etc., others are in combination with mechanisms in which sawdust, bran, peanut shells, etc., are used. These machines are used to clean dirt and oil from the steel when required by the customer.

Most all cold rolled steel is oiled before shipping. The steel requires great care, especially the light, soft stock, as bending and scratching are very easily done. It is therefore shipped in boxes, burlap wrapped, bundled or banded. It may be shipped loose in box cars.

Cold rolling of steel is largely an art. This article is not intended to completely cover the subject, but is presented merely to give a general idea of the things that enter into this very interesting and useful branch of the steel industry.

Electrical Rolling Mills

By D. W. BLAKESLEE*

Rail Mills

THE rolling of rails is very frequently done in mills especially designed for that purpose, and not for any other shape. For economical reasons quantity production is of great importance, and therefor only the larger steel manufacturers make rails. Some mills are used for rolling structural shapes as well as rails. Although rails are now rolled on a large scale of output in nine or ten different works in the United States, the shapes and sizes are standardized. This requires very fine roll designing and turning, also good operation and maintenance of the mills to keep the dimensions required by the standards of the American Society

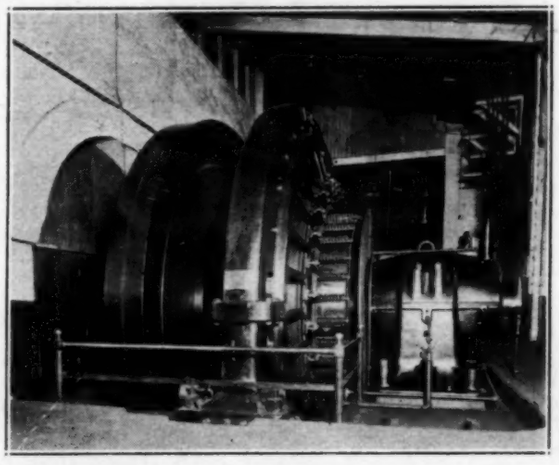


FIG. 1.

of Civil Engineers and the American Railway Association. The size of the rail is specified by its weight per yard. There are also requirements to be met by chemical analysis and mechanical testing of the finished rail. The A.S.C.E. rails run from 60 to 100 pounds, and the A.R.A. rails are in two series from 60 to 100 pounds. Other rails are also rolled; heavier, lighter and special shapes.

*Elec. Engr., Jones & Laughlin Steel Corp., S. S. Works, Pittsburgh, Pa.

Early practice was for rail mills to be constructed with three-high stands in one train. Now the usual rail mill consists of two to four trains of one or more two-high or three-high stands in each. There are also a few reversing mills having two-high stands.

Rails are frequently rolled directly as the steel passes from the blooming mill, so using the heat required for the first rolling of the ingot. This saves the expense of reheating but does not give opportunity for inspection of the bloom nor chance to do any chipping out of any faults which might be present in it. Some purchasers believe that the reheating system is better, and some mills do it.

In order to obtain maximum production without unduly speeding up of the rolls, the stands are spaced far apart, so that a rail is in only one stand at a time, although there are a number of

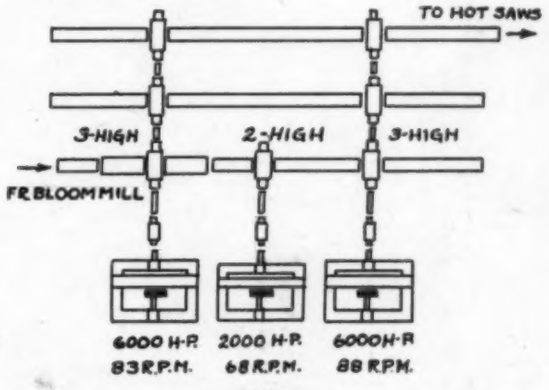


FIG. 2.

pieces of steel in the mill at once. The first motors used for steel mill roll drive were on an 18 in. rail mill in the Edgar Thomson Works of the Carnegie Steel Co. These motors were installed in 1905 for use in rolling 12 to 40-pound rails. Two motors each of 1,500 h.p., direct current, are used; one to drive two three-high stands, and the other one three-high and one two-high stands. One of these motors is shown in Fig. 1.

The layout of the 28 in. rail mill at the Gary plant is indicated in Fig. 2. The hot metal comes

from the blooming mill shear directly into the rail mill. The two trains, which have three stands each, in which are made the first and last passes, respecitvely, are each driven by 6,000 h.p. low-speed induction motor. The one two-high stand is operated by a 2,000 h.p. motor of still lower speed. This mill can produce an output of 2,000 tons of rails in each ten-hour turn. After leaving the mill, the rail is cut

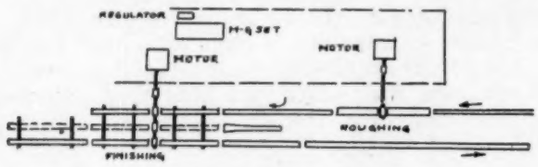


FIG. 3.

into standard lengths by means of motor-driven hot saws speed about 30 ft. apart. Since the rail shortens as it cools, about ten per cent additional length must be provided for shrinkage.

In rolling of rails there are three operations pertormed; roughing, forming, finishing. In the roughing stage the bloom is elongated and reduced in section. In the next stage the steel gradually approaches the form of the finished section of the rail. In the last pass the smooth surface is imparted to the rail. Fig. 3 shows the arrangement of the 28-in rail and structural mill of the Inland Steel Co. The roughing mill is a 34-in. tow-high stand driven by a reversing motor. Another direct current motor which is non-reversing drives a train consisting of

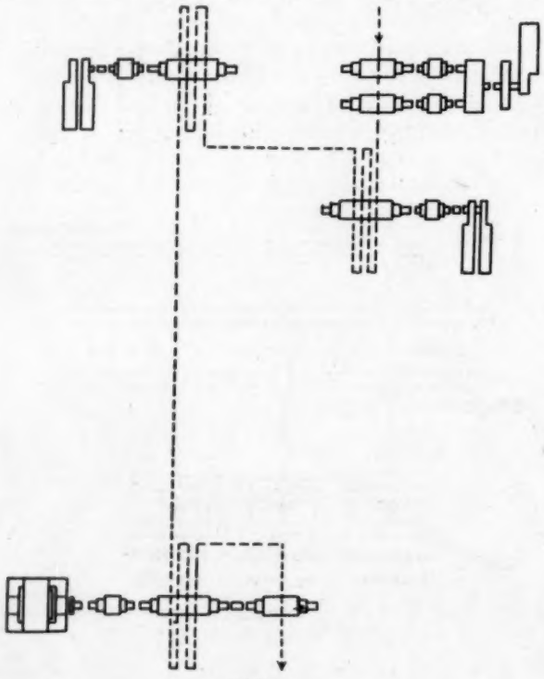


FIG. 4.

two three-high and one two-high stands for shaping and finishing, respectively. Each motor has its own generator, coupled to a common motor in conjunction with a flywheel. So that the flywheel of the motor generator set may give up its energy when required, a liquid slip regulator is employed.

An unusual rail mill is indicated in Fig. 4. This mill is at the Lackawanna plant of the Bethlehem Steel Corporation, has no three-high stands. All stands are driven by steam engines except those in the finishing train, which are operated by a reversing motor.

The energy required to roll rails depends upon the amount of elongation, among other factors. The relation between kw.-hrs. per ton and elongation is shown in Fig. 5.

Beside the main roll drives there are many auxiliary equipments which may be motor driven to the best advantage; these are tables, pushers, transfers, pull-overs, edging devices, kick-offs, cambering machines, hot saws, cold saws, gag presses, drills, shears, punches, etc.

Structural Mills

Structural mills, as the name indicates, are mills designed for rolling shapes for the fabrication of buildings, bridges, and other structures. The more common of these sections are angles, channels, I-beams, Tees and Zees. The sizes are designated by the weight per foot and the over-all dimensions. As mentioned before, a mill may be used for rolling

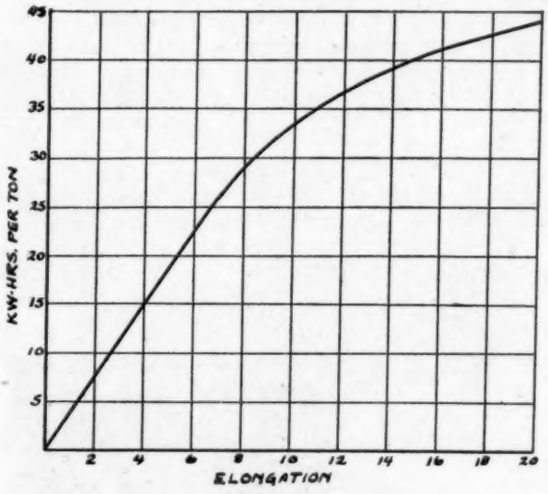


FIG. 5.

structural shapes as well as for rails. Fig 6 shows the motor driving the three-stand train, as indicated in Fig. 3, which is the layout of such a mill.

The design of the mill depends upon the section and the size of the product. The mill usually consists of a train of three or four three-high stands, which are served by traveling tables. In common practice the steel is reheated just before it is conveyed into the structural mill. There are, however, some mills which take the steel directly from the billet mill. After the shape is rolled it is cut into the desired lengths by means of the hot saw, and then goes to the hot bed. After the steel is cool, it is straightened either by means of gag press or cold rolls. In some cases it is then cut into shorter lengths by a cold saw.

Fig. 7 shows the 1800 h.p., alternating current motor driving the 22 in. billet and structural mill of the Scullin Steel Co., St. Louis, Mo. Wound rotor induction motors with flywheels are used on all continuous mills. When heavier sections are rolled it is desirable that the speed be reduced, therefore constant horsepower, adjustable speed

equipment is used. Standard reversing equipment may be used on two-high stands.

On an 18 in. mill in the Saucon Works of the Bethlehem Steel Corporation, are two three-high stands and one two-high stand, driven by one 1,500 h.p., 133 to 81 r.p.m., adjustable speed, constant power motor. In the South Works of the Illinois

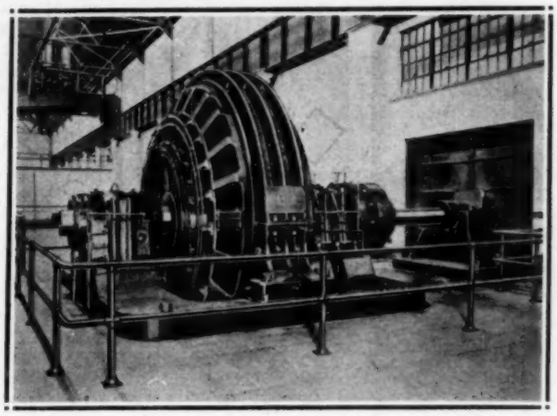


FIG. 6

Steel Co. there is a structural mill with six two-high and two three-high stands in tandem. One 3,000 h.p. motor, with flywheel, drives the first seven stands through a line shaft, and an induction motor rated at 1,000 h.p., 133 r.p.m., operates the finishing stand. The Phoenix Iron Co. replaces steam drive of two mills by electric drive. The 24-in. structural mill consists of four three-high stands, which are driven by a motor which obtains its energy from a flywheel motor-generator set. The 22-in. mill has three three-high stands driven by a wound rotor induction motor through a gear unit equipped with a flywheel.

The Carnegie Steel Co. is now installing at the Homestead Works an up-to-date 28-32 in. finishing

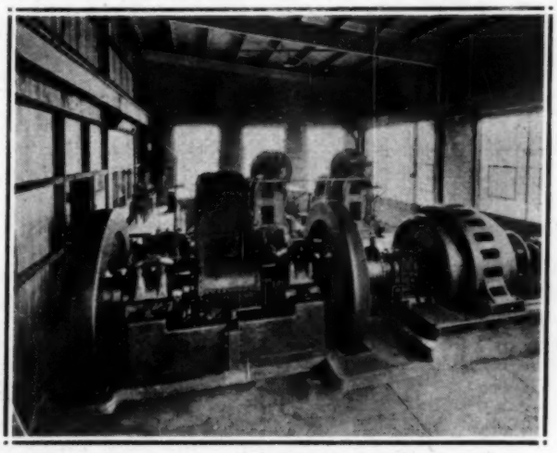


FIG. 7.

mill. It will be driven by a 6,000 h.p. induction motor, 6,600 volts, 3 phase, 25 cycle, 98 r.p.m. Coupled between the motor and the mill will be a 130,000-pound flywheel, 27 ft. 6 in. in diameter. Another set of modern drive equipments is going into the Lackawanna plant of the Bethlehem Steel Co., on the 35-28 in. structural mill. It includes:

1—3,500 h.p. (continuous rating), 700 volts, 50 to 120 r.p.m., direct current, single unit, reversing motor.

1—5,000 h.p. (continuous rating), 700 volts, 75 to 120 r.p.m., direct current, single unit, reversing motor.

1—Flywheel motor-generator set, consisting of:

1—3,000 kw., 700 volt, direct current generator;

2—2,100 kw., 700 volt, direct current generators in parallel;

1—150,000-pound, cast steel flywheel;

1—7,500 h.p., 6,600 volt, 3 phase, 23 cycle, 375 r.p.m. induction motor.

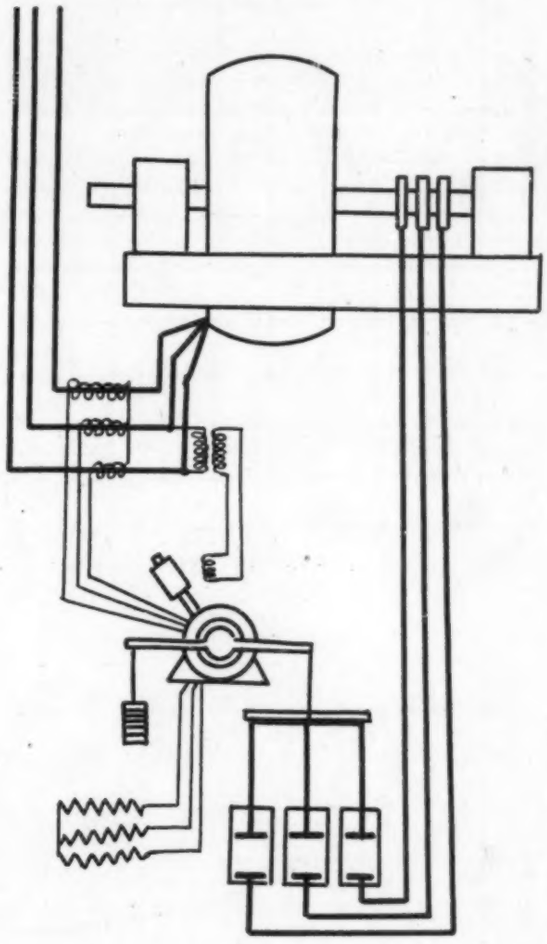


FIG. 8

There will be magnetic field controllers with foot-operated master switches for reversing the motors, and liquid slip regulators for secondary control of the induction motor.

It may be in order here to indicate the operation of the liquid slip regulator. See Fig. 8. Whenever power is off the main motor the low-voltage release coil is de-energized and the electrodes are held at their highest position. Under this condition the resistance in the secondary circuit is maximum. In starting the motor the primary circuit is first closed. This places power on the primary with all resistance in the secondary. The auxiliary arm is then raised until it is engaged by the low-voltage device. Raising this arm releases the moving electrodes,

which start to descend. As the electrodes approach each other, the resistance between them becomes less, and the current in the primary of the main motor increases, increasing the torque of the torque motor. At some point the torque, due to the weight

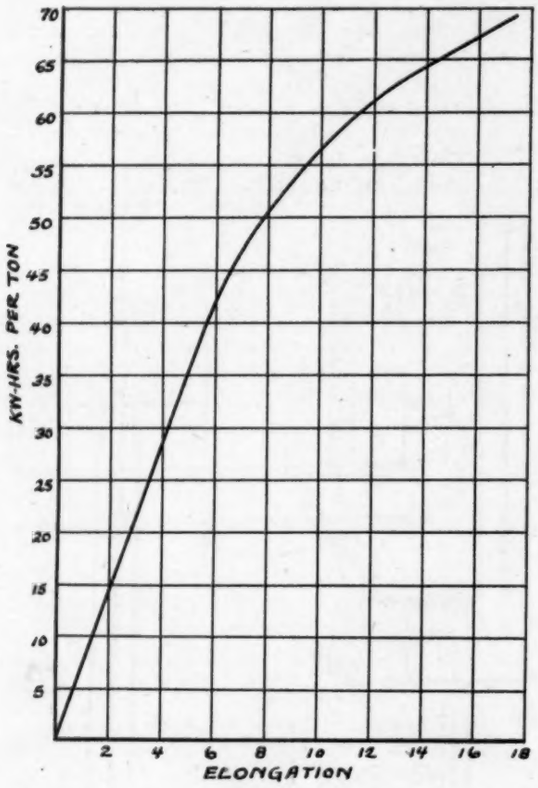


FIG. 9.

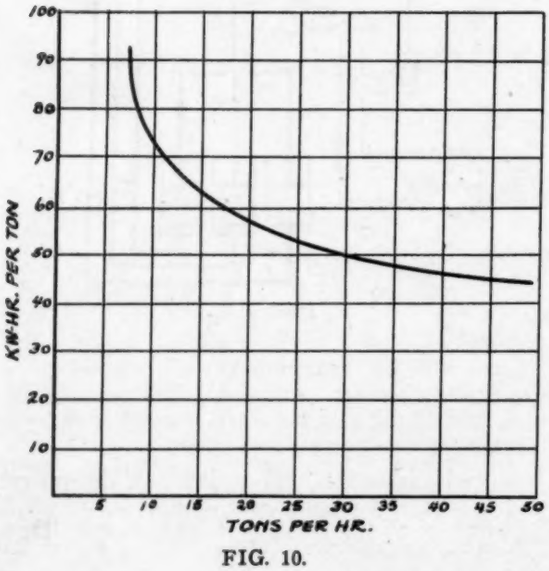


FIG. 10.

of the electrodes, will be just balanced by the combined torque of the motor and counterweights; the electrodes will float at this point. As the motor accelerates, this condition of equilibrium is maintained, the electrodes approaching each other at a rate which maintains the input to the main motor at a constant value. When the motor reaches full speed the electrodes are at their lowest position and the secondary of the motor practically short-circuited.

In the tabulated list is shown the auxiliary motor equipment required for structural and rail mills:

Auxiliary Motor Equipment for Structural Mill

It.	Application	Req.	HP.	RPM.	Wdg.	Con.	Plug	Rev.
1	Trav. Table Rolls	4	50	525	Ser.	Mag.	Yes	Yes
2	Trav. Table Tilting	4	80	520	Cpd.	Mag.	No	Yes
3	Trav. Table Travel	4	50	525	Ser.	Mag.	Yes	Yes
4	Trans. fr. Furnace	1	40	540	Cpd.	Mag.	Yes	Yes
5	Furnace Tables	4	40	525	Ser.	Mag.	Yes	Yes
6	Mill appr. Table	2	40	525	Ser.	Mag.	Yes	Yes
7	Furnace Pusher	2	80	480	Ser.	Mag.	Yes	Yes
8	Runout Tables	1	80	480	Ser.	Mag.	Yes	Yes
9	Hotbed Pull Overs	4	80	520	Cpd.	Mag.	Yes	Yes
10	Edging Device	2	30	550	Cpd.	Mag.	No	Yes
11	Hot Bed Tables	4	40	525	Ser.	Mag.	Yes	Yes
12	Kickoff Mechanism	2	30	550	Cpd.	Mag.	No	Yes
13	Cambering Mach	1	30	600	Cpd.	Drum	No	Yes
14	Straightening Mach.	1	150	730		GB	No	No
15	Hot Saw	1	150	730		GB	No	No
16	Cold Saws	1	150	730		GB	No	No
17	Hot Saw Feed	1	15	300/1200	Sh.	Mag.	No	Yes
18	Cold Saw Feed	2	15	300/1200		Mag.	No	Yes

Items 1 to 13, inclusive—Backgeared.
Items 2, 3, 12—Brakes.
Items 2, 10, 12—Dyn. Braking.
Items 2, 12, 17, 18—Geared Limit Switch.
Items 4, 9—Track Limit Switch.
Item 7—Hatchway Limit Switch.

Auxiliary Motor Equipment for Rail Mill Finishing Department

Application	Req.	HP.	Wdg.	RPM.	Control
Gag Press	2	5	Squirrel Cage	975	Starter
Drill Press	6	5	Squirrel Cage	975	Starter
Vertical Shears	2	10	Squirrel Cage	975	Starter
Punches	2	5	Squirrel Cage	975	Starter
Roll Lathe	2	25	Shunt	400/1200	Drum
Roll Lathe	1	15	Shunt	400/1200	Drum
Roll Lathe	2	10	Shunt	400/1200	Drum

When rolling is begun the regulator automatically limits the motor input to the value for which it is set, and with the proper relation between flywheel effect and load will maintain approximately constant input. When the input tends to exceed the value for which the regulator is set, the torque motor causes the electrodes to separate, thereby introducing slip resistance into the motor secondary, causing a corresponding reduction in speed, and allowing the flywheel to take the peak load. After the peak has passed, the torque motor allows the electrodes to approach each other, still maintaining the load at constant value until the motor again reaches full speed. The value of the load at which the regulator will open is easily adjusted to follow ordinary operating conditions by changing the number of counterweights; also the series operating transformer is provided with 80, 100, 125 and 150 per cent taps to take care of the larger adjustments. Thus, when a mill is first put into service to 80 per cent tap can probably be used, the connections being moved to a higher tap as the operation is speeded up and the tonnage increased. In case a quick stop is desired, the motor can be plugged. To do this the primary circuit is first opened. The electrodes immediately move to their highest position, after which the primary can be closed in the "reverse" direction. This reverses the power on the motor and brings is quickly to rest.

In Fig. 9 is given an indication of the average relationship between energy per unit of output of the structural mill to the elongation of I-beams rolled.

From actual tests on three individual mills rolling I-beams, the following rates are obtained:

Mill	18 lb. I-beam	12 lb. I-beam
1	38.7 kw.-hr. per ton	47.2 kw.-hr. per ton
2	58.0 kw.-hr. per ton	63.5 kw.-hr. per ton
3	53.5 kw.-hr. per ton	72.9 kw.-hr. per ton

Fig. 10 shows roughly the relationship between rate of energy and the rate of output. The values for an individual mill will depend upon its construction and conditions, which may produce figures from 5 to 15 per cent either side of the curve.

*Design and Test of Susquehanna Station Metropolitian Power Company**

By J. A. POWELL†

THE Susquehanna River Station of the Metropolitan Power Company is located on the east bank of the Susquehanna River, at Middletown, Pa., approximately twelve miles southeast of Harrisburg.

At the time of the selection of this site there were two sites in prospect; one on the Susquehanna River at Middletown, and the other on the Delaware River at Holland, N. J. As additional capacity on the western end of the system seemed to be required first, and for the sake of continuity of service, the station was located at Middletown. Fig. 1 shows a map of the Pennsylvania-New Jersey power system and shows the location of the station near its western end. The first unit of the station is completed. It was designed and built and is operated by The W. S. Barstow Management Association, Inc.

In designing the foundations for the station, it was necessary to take into account the fact that the level of the water in the river in times of flood rises to a height of 26 feet above the low water level of the river. The arrangement of the equipment had to be suitable for both the high and low water conditions, and consequently in order to insure an ample supply of water at times of low water it was necessary to locate the level of the condenser basement approximately at the low water level of the river. To provide against flood conditions then, it was necessary to make the condenser pit water tight and consequently it was waterproofed with a separate outside waterproofing for a height of 32 feet above its base or 27 feet above the low water level of the river. It had to be made strong enough to withstand the 32 feet of water pressure and heavy enough to keep it from floating in high water which necessitated a reinforced, concrete floor or pad 6 feet 3 inches thick.

The river at the station site is very broad and shallow and there was a possibility that in extremely cold weather the water due to its shallowness might freeze to a depth which would make it almost impossible to obtain sufficient water for condensing. For this reason the station was set back approximately 400 feet from the normal shore line of the river and water supplied to it by means of an artificial bay or pond.

It was then arranged so that water which had passed through the condensers could be turned back into the pond in very cold weather or returned to the river below the point of inlet to the pond. The temperature of the water is raised sufficiently in the condensers to keep the pond free from excessive ice when the water is returned to it.

By locating the station back from the river bank it was possible to put in its foundations without the use of sheet piling which reduced the construction costs materially.

The chimneys for the station were located to the rear of the boiler room with their bases at grade elevation. The flues or breechings between the boilers and the chimneys were located in the boiler room basement, thereby utilizing space which would otherwise have been wasted. It was, therefore, possible to locate the induced draft fans at a low elevation.

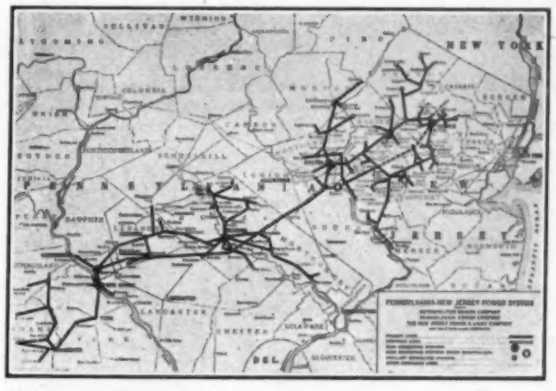


FIG. 1.

Locating the chimneys outside of the building and placing the fans on a lower floor of the boiler room resulted in a much more economical building than would have been necessary if the chimneys had been supported above the boilers and the fans had been placed at a higher elevation. This is evident since the structural steel frame of the building in the latter case would have to be rigid enough to withstand the vibrating loads of the induced draft fans and strong enough to carry the added weight of the chimneys and wind pressure.

The design of the station was begun during the summer of 1922, at the time when there was a decided trend toward more efficient steam plants, due mostly to the higher price of coal. At that time the questions of steam pressure and superheat, as well as the use of economizers and feed water heating

*Presented at Philadelphia District Meeting at Reading, Pa., December 6, 1925.

†Eng., Metropolitan Power Co., Middletown, Pa.

by means of steam bled from the main turbine, were very much unsettled. At that time also there was no accepted and approved piping standard for steam pressures above 250 pounds per sq. in. and the various piping manufacturers were recommending widely different standards of flange dimensions for the higher pressures. Pulverized fuel was considered to be only in an experimental stage. The use of economizers were considered to be justified only where the cost of coal was very high and where extremely high load factors were encountered. The condensate was usually heated either by a house turbine or by steam driven auxiliaries.

In the ultimate analysis, a power plant is really a manufacturing plant for converting fuel into electrical energy, and in the production of electrical energy or power, there are four main costs, namely, materials, maintenance, labor and fixed charges.

In considering the matter of materials, the principal item is fuel, the price of which varies with different locations, depending upon the freight rate, which is affected by the proximity of the source of supply. Consequently, in a plant where fuel is high in cost, more efficiency can be justified than in a plant where fuel is cheap.

In plants of similar design the cost of labor decreases as the size or capacity of a plant increases. In the more complicated plants designed for ex-

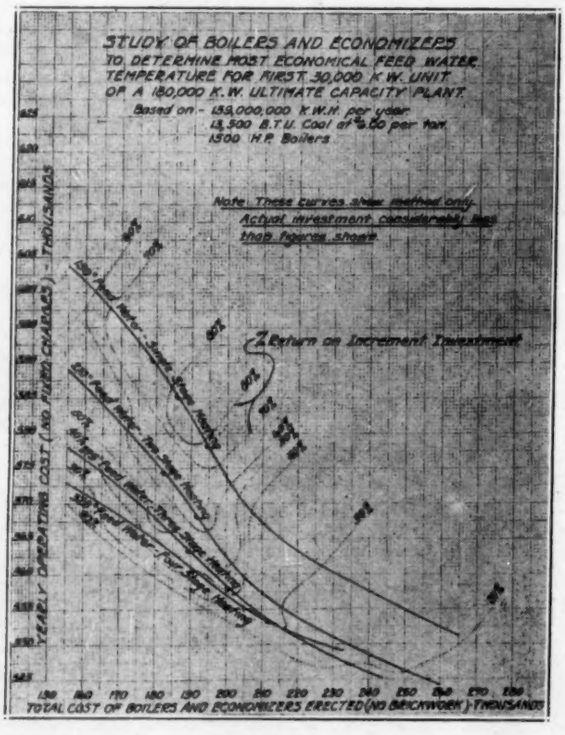

STUDY OF BOILERS AND ECONOMIZERS
TO DETERMINE MOST ECONOMICAL FEED WATER
TEMPERATURE FOR FIRST 30,000 K.W. UNIT
OF A 150,000 K.W. ULTIMATE CAPACITY PLANT.
Based on - 139,000,000 K.W.H. per year
13,500 B.T.U. Coal at $2.50 per ton
1500 H.P. Boilers
Note: These curves show method only.
Actual investment considerably less
than figures shown
% Return on Increment Investment
YEARLY OPERATING COST (NO FIXED CHARGES) - THOUSANDS
TOTAL COST OF BOILERS AND ECONOMIZERS ERECTED (NO BRICKWORK) - THOUSANDS

FIG. 2.

tremely high efficiencies, the cost of labor is increased, due to necessary additional attendance. The cost of labor per kilowatt-hour, however, does not vary sufficiently to affect the design seriously, except that in all cases simplicity should be foremost in the designer's mind.

Cost of maintenance in the power plant is affected largely by the type of equipment which is installed and consequently the cost of maintenance in the more complicated plants is necessarily higher than it is in plants having more simple equipment.

In considering the matter of fixed charges consisting of interest, taxes, depreciation, etc., it should be remembered that they are constant and must be paid year after year, without being affected by fluctuations in the cost of fuel and labor. It is important, therefore, that a detailed study pertaining to each group of equipment purchased be made, so as to be

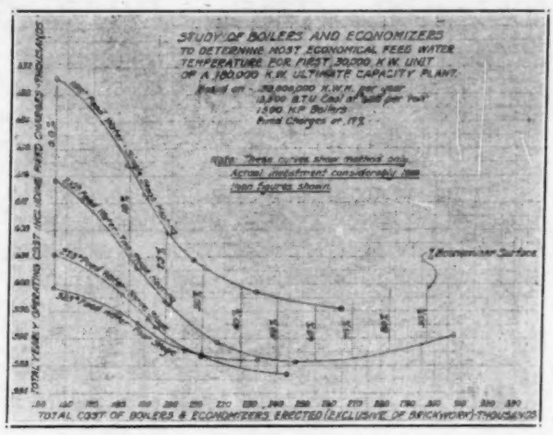

STUDY OF BOILERS AND ECONOMIZERS
TO DETERMINE MOST ECONOMICAL FEED WATER
TEMPERATURE FOR FIRST 30,000 K.W. UNIT
OF A 150,000 K.W. ULTIMATE CAPACITY PLANT.
Based on - 139,000,000 K.W.H. per year
13,500 B.T.U. Coal at $2.50 per ton
1500 H.P. Boilers
Fixed Charges at 11%
Note: These curves show method only.
Actual investment considerably less
than figures shown
% Return on Increment Investment
TOTAL YEARLY OPERATING COST INCLUDING FIXED CHARGES - THOUSANDS
TOTAL COST OF BOILERS & ECONOMIZERS ERECTED (EXCLUSIVE OF BRICKWORK) - THOUSANDS

FIG. 3.

reasonably sure that no apparatus is installed that cannot earn its fixed charges.

With the above in mind in addition to considering the justification of efficiency on one particular piece of apparatus, studies were made on the whole plant as a unit to determine the maximum amount of efficiency that could be justified without having the initial cost excessive.

An investigation covering existing pulverized fuel plants indicated that there was a great future in pulverized fuel, but that there was a great deal of experience to be gained. It appeared that at the Susquehanna Station site a large quantity of river coal could be obtained directly from the river and in the immediate vicinity at a very low cost. Large quantities of the finer grades of fresh mined anthracite could also be obtained from the Shamokin, Sunbury, Pottsville and Lykens districts, all coming within the lower freight rate zones. As these fuels were very cheap and could be stored in enormous piles as an emergency fuel without danger of deterioration, a great deal of thought was given to coal burning apparatus which could utilize this fuel as well as bituminous coal.

It appeared that by installing pulverized fuel equipment the station could be made independent of any one source of coal supply with its accompanying strikes, lock-outs, etc., although the art of pulverizing some grades of anthracite and river coal was not so far advanced as the art of burning it. It seemed best that several different mills should be tried and consequently a separate preparation building was decided upon so that changes in the equipment could be made without disturbing any part of the main plant, and today there are three different manufacturers' mills in operation.

In considering the boilers for the station, a study was made in order to determine the most economical type and size of boilers, the most economical feed

water and flue gas temperatures, as well as the economy to be obtained by the use of economizers.

The curve Fig. 2 shows the estimated total yearly plant operating cost, insofar as it is affected by the boilers and economizers including the fixed charges, plotted against the total investment necessary for boilers and economizers of various sizes for various stages of feed water heating. This curve indicates that three stage heating is most economical where economizers are used in connection with stage feed water heating by means of steam bled from the main turbine. On account of the slight difference in economy, as shown by the curves between two stage and three stage heating, two stage would probably be selected on account of its greater simplicity of mechanical appliances and of operation. The curve indicates also that where economizers are not considered, four stage heating is justifiable The figures on this and the following two curves are not actual costs or investment but are relative and show the method only.

Figure 3 shows the estimated yearly operating cost, with the fixed charges not included, plotted against the total investment for boilers and economizers. Contour lines are plotted on this curve which show the per cent return on increment investment for the various degrees of feed heating, and indicate between what limits additional investment for greater efficiency or lower operating cost will produce a given return on the additional investment necessary to attain this lower cost.

Fig. 4 shows the efficiency of the same size boilers equipped with various sizes of economizers, plotted against the total cost of boilers and economizers. The curve indicates the high and low price for straight tube boilers without economizers as well as the cost of bent or curved tube boilers, without and with varying quantity of economizer surface. The curve indicates that for the same amount of capital

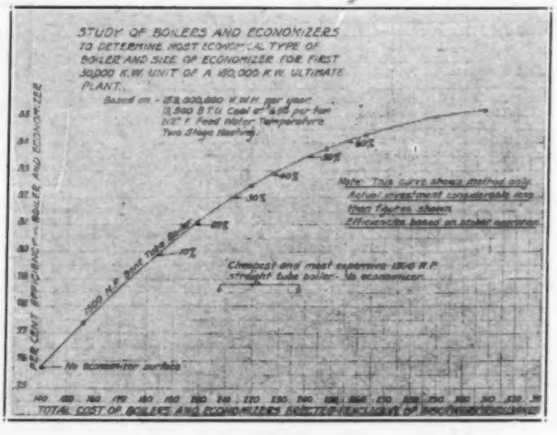

STUDY OF BOILERS AND ECONOMIZERS
TO DETERMINE MOST ECONOMICAL TYPE OF
BOILER AND SIZE OF ECONOMIZER FOR FIRST
30,000 K.W. UNIT OF A 150,000 K.W. ULTIMATE
PLANT.
Based on - 153,000,000 K.W.H. per year
13,500 B.T.U. Coal at $2.00 per ton
210° F. Feed Water Temperature
Two Stage Heating
Note: This curve shows method only
Actual investment considerable less
than figures shown
Efficiencies based on boiler operation
Cheapest and most expensive 1500 H.P.
straight tube boiler - No economizer
1500 H.P. Bent Tube Boiler
No economizer surface
PER CENT EFFICIENCY — BOILER AND ECONOMIZER
TOTAL COST OF BOILERS AND ECONOMIZERS SELECTED (EXCLUSIVE OF BUILDING)

FIG. 4.

necessary to purchase the cheapest straight tube boilers without economizers a much greater efficiency can be secured by purchasing bent tube boilers with economizers. It indicates that where economizers are used, a much less efficient and less expensive boiler can be justified, since efficiency in the boiler is not so important when economizers are used. As the bent tube type of boiler is inherently cheaper than the straight tube type, their use in combination with economizers is unquestionably most economical, within certain pressure limits, even though they in themselves may be less efficient than the straight tube type. Studies similar to the above were made on all sizes and types of boilers as well as all possible combinations of boilers and economizers.

A study was made in order to determine the difference in economy between the single pass and the two-pass type of surface condensers, as well as the most economical quantity of condenser surface using

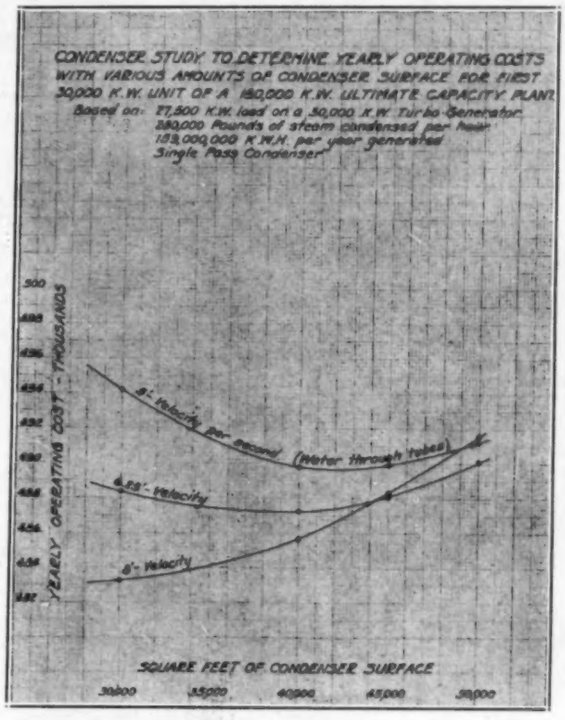

CONDENSER STUDY TO DETERMINE YEARLY OPERATING COSTS
WITH VARIOUS AMOUNTS OF CONDENSER SURFACE FOR FIRST
30,000 K.W. UNIT OF A 150,000 K.W. ULTIMATE CAPACITY PLANT
Based on: 27,500 K.W. load on a 30,000 K.W. Turbo-Generator
280,000 Pounds of steam condensed per hour
153,000,000 K.W.H. per year generated
Single Pass Condenser
YEARLY OPERATING COST - THOUSANDS
8'- Velocity per second (Water through tubes)
6.29'- Velocity
5'- Velocity
SQUARE FEET OF CONDENSER SURFACE
30000
35000
40000
45000
50000

FIG. 5.

circulating water velocities of from five to ten feet per second. This study was based on a 27,500 KW load on a 30,000 KW Unit, 280,000 pounds of steam condensed per hour, and considered the effect of vacuum on the operation of the main turbine and the extent to which this vacuum could be utilized. It considered also the average monthly circulating water temperatures, pumping costs, initial cost of condenser, tube maintenance, etc., and was designed to indicate the most economical condenser.

The curve Fig. 5 shows the yearly plant operating cost, insofar as it is affected by the condenser, in thousands of dollars for various sizes of single pass condensers with different velocities for circulating water.

In considering the matter of steam pressure for the station it appeared that the various boiler manufacturers were at that time reluctant to attempt building bent or curved tube boilers for pressures higher than 350 to 400 pounds per sq. in. gauge, and as pressures higher than this seemed to be somewhat in the experimental stage it was decided to build the plant for an operating steam pressure of 350 lbs. gauge. In considering the matter of superheat or total steam temperature it appeared that a total temperature of 680°F. was high enough when the stage of development of materials for handling high temperatures was considered.

Just prior to the design of this station a steam pressure and superheat of 200 pounds per sq. in. and. 100° superheat was considered good practice. By adopting the higher conditions of pressure and superheat noted above for the Middletown Plant, there was a betterment due to the difference between 350 lbs. and 200 lbs. pressure of 5.3 per cent of the coal consumption, and due to the difference between 220° and 100° superheat a betterment of 5.7 per cent of the coal consumption of the plant.

There was a betterment due to the installation of the economizers of 6.5% of the coal consumption of the plant while the bleeder heating system also causes a betterment of 5.3%.

	Saving in Coal
Higher pressure	5.3 per cent
Higher superheat	5.7 per cent
Economizers	6.5 per cent
Bleeder Heaters	5.3 per cent

It was decided to provide for bleeding the turbine at two stages for heating feed water and to provide a third bleed point on the turbine for the future installation of evaporators if found advisable. It was found that very good water could be obtained from a well at the station site and for the present a Permutitt system of water treatment was installed. An intimate contact vacuum heater was installed to remove the oxygen from the condensate and makeup water and to maintain a constant feed water temperature, steam being supplied to it from the exhaust of the dual driven equipment.

The principal equipment in the main part of the station consists of:

1—30,000 KW. 18000 R.P.M., 17 stage General Electric Co. Turbo-Generator.
1—45,000 sq. ft Single Pass Condenser—Wheeler Condenser & Engineering Co.
4—1477 H.P. Connelly Boilers—Lopulco Pulverized Fuel Burning Equipment.
2—7500 sq. ft. Sturtevant Economizers.
2—7700 sq. ft. Foster Economizers.

The principal equipment in the coal preparation plant consists of:

1—Hardinge Mill.
2—46" Fuller Air Mills.
2—46" Raymond Air Mills.
2—Wood Steam and Flue Gas Dryers.
2—Randolph Steam and Flue Gas Dryers.
2—Fuller-Kinyon Pumps.

Test

During the first two weeks of July, 1925, three tests were made upon the Susquehanna Station. The first test, hereinafter designated as Test PT. was a preliminary test started on June 30th and continuing for 70.6 hr. This test was conducted under the supervision of the engineers of the Metropolitan Power Company and was observed by Mr. K. S. Wingfield, representing the firm of Murray & Flood.

The second test, hereinafter designated as Test OT, was the official test conducted under the direct supervision of Murray & Flood. This test was of 72.2 hr. duration. The station was operated for both tests under conditions representative of normal operation for the time of year when made. An average plant output of 25,150 K.W. was carried during the test with a maximum hour of 35,453 K.W. and a minimum hour of 18,227 K.W. The maximum hour was attained under unfavorable conditions of excessively high circulating water temperature and with the steam superheat approximately 10 per cent below that guaranteed by the equipment manufacturers.

The third test conducted, and hereinafter designated as Test ST, was started on July 10th and continued for 22.5 hr. This test was conducted under the supervision of Murray & Flood, and was made to ascertain the efficiency of the boiler plant which might be realized under favorable conditions, and also, to obtain an approximate check of the steam consumption of the turbine unit. For the purpose of this test bleeding from the turbine was practically eliminated, resulting in a lower temperature of water being fed to the economizers than was the case in Test OT, and also resulting in the utilization of practically all of the superheated steam by the turbine in the production of energy.

Data Obtained During the Tests

Inasmuch as these tests were run to determine the plant efficiency, special pains were taken to see that no error occurred in weighing the coal or measuring in K.W.H. output. All other figures, while very useful, were incidental. All coal was weighed in a large weigh larry that serves the raw coal bunkers, each weight being checked by two men. This means that the results given are based on weight of coal actually paid for, and includes all losses incidental to transporting and pulverizing.

The pulverized coal bunkers were very carefully calibrated so that any variation at the beginning and end of the test could be noted and corrections made, if necessary.

All instruments, such as thermometers, calorimeters, scales, water meters, watt meters, etc., were calibrated before and after each test, and, in fact, the water meters were calibrated several times during the test.

Every precaution was taken in obtaining the samples of coal from which the b.t.u. content was to be determined. These samples were ground and sub-divided in the usual way and put into air tight containers for analysis. Analysis was not only made by our own laboratory but by the Bureau of Mines and the Combustion Engineering Company. Samples of coal from pulverized fuel bins and samples of ash from the ash pit and flue were also carefully obtained and analyzed.

TABLE D-2

CHARACTERISTICS OF COAL USED DURING TEST

Line		Unit	Test OT	Test ST
	Coal			
1	Kind Used		Bituminous	Bituminous
1A	Mine		Sterling	Sterling
	Ult. Analysis raw coal dry basis			
2	Carbon	Per cent	82.73	
3	Hydrogen	"	4.71	
4	Nitrogen	"	1.63	
5	Sulphur	"	1.55	
6	Oxygen	"	3.13	
7	Ash	"	6.25	
	Prox. Analysis raw coal as received			
8	Moisture	"	2.47	2.23
9	Volatile Matter	"	23.58	23.62
10	Fixed Carbon	"	67.85	67.97
11	Ash	"	6.08	6.18
12	Sulphur	"	1.46	1.54

13	Heat value per lb.	B.t.u.	14,324	14,385
	Fineness of Pulverized Fuel			
14	On 100 mesh screen	Per cent	9.43	8.5
15	On 140 mesh screen	"	6.47	6.5
16	On 200 mesh screen	"	8.20	8.0
17	Through 200 mesh screen	"	75.90	77.0
	Ash			
18	Combustile in ash from ash pit	"	0.0	
19	Combustible in Flue Dust from economizers	"	36.7	41.0
20	Combustible in Flue Dust from soot hoppers	"	34.8	

Coal Preparation and Transportation

Table D-3 following shows short tons of coal milled and also the energy required for handling, transporting and feeding coal to the boilers. On the official test OT a total of 15.63 K.W.H. per short ton of coal was required for its preparation and handling, which amounts to 0.81 per cent of the plant output. In the design of the station, in making a comparison between the cost of operation with pulverized fuel and the cost of operation with stokers, a figure of 20 K.W.H. per ton was used.

TABLE D-3

PREPARATION AND TRANSPORTATION OF COAL

Line		Unit	Test OT	Test ST
21	Total coal transported and milled	Net tons	1,008.4	262.9
22	Coal milled per hour—Average	"	10.8	11.7
23	Energy per ton of coal milled—Average	Kw.-hr.	10.06	9.89
	Energy for raw coal handling			
24	Total	"	489	163
25	Per net ton of coal	"	0.49	0.62
	Energy for coal transportation			
26	Total	"	1,224	408
27	Per net ton of coal	"	1.21	1.56
	Energy for lighting and losses			
28	Total	"	2,864	457
29	Per net ton of coal	"	2.84	1.74
	Total energy for preparation & trans.			
30	Total	"	14,715	3,630
31	Per net ton of coal	"	14.60	13.81
	Energy for furnace coal feeders			
32	Total	"	1,044	252
33	Per net ton of coal	"	1.03	0.96

The distribution of energy required for the preparation and transportation of coal was as follows, during test OT:

ITEM	KWHr. per Short Ton of Coal	Per Cent of Total Energy	Per Cent of Plant Output
Mills	10.06	64.2	.52
Raw coal handling	.49	3.1	.026
Coal Transportation	1.21	7.7	.062
Lighting and losses	2.84	18.4	.149
Furnace feeders and prim. fans	1.03	6.6	.053
Total energy for coal prep. and transportation	15.63	100.0	.810

The results of nine months' run on this plant indicate that the kilowatt hours used for grinding per short ton depend almost entirely upon the coal being ground. Stirling coal is very friable. Some of the other bituminous coals are harder and take more energy, and with the anthracite coal nearly double the amount of energy is taken.

It is interesting to note the results for the past five months. In June, 17.1 K.W.H. were used for grinding coal. In July, 14.9. In August, 16.5. In September, when a good deal of hard coal was used, 18.2; and in October, 16.4.

Performance of the Boiler Plant

During the course of test OT, the boilers were operated through a range of from 174 per cent of rating during the minimum hours of output of 16,100 kw. on July 8th, from five to six P. M., to a maximum of 288 per cent of rating during the maximum hour's output of 33,400 kw. on July 10th, between nine and ten A. M., with an average of 224 per cent for the entire test. The variations in the principal pressures, temperatures and quantities over this range during test OT, were as follows:

ITEM	Maximum	Average	Minimum
Per cent builders rating	288	224	174
Plant output in kw.	33,400	25,100	16,100
Temperature of gases—			
(a) 4th pass of boilers		584.3	
(b) Inlet to economizers		568.4	
(c) Outlet of "		316.3	
(d) Drop in "		252.1	
Water temperatures			
(a) At inlet of economizers		212.2	
(b) At outlet of "		295.3	
(c) Rise in "		83.1	
Super-heat in °F		194.4	
Steam pressure drop through superheaters		7.8	
Steam pressure drop between superheaters and turbine nozzle		14.0	

On test ST the loading of the boilers was kept much more constant, varying between a minimum of 187 per cent during the hour of minimum output and a maximum of 204 per cent during the hour of maximum output.

TABLE D-4

PERFORMANCE OF BOILER PLANT

Line		Unit	Test OT	Test ST
	Total Quantities			
34	Duration of Test	Hr.	72,167	22,517
35	Water fed to boiler plant	Lb.	22,658,753	5,820,000
36	Saturated steam generated	"	665,853	161,490
37	Superheated steam generated	"	21,744,000	5,587,800
38	Make up	"	248,900	70,800
39	Coal burned in furnaces	"	2,016,294	524,115
	Average Pressure			
40	Steam — No. 3 drum outlets	lb/sq. in.	349.1	347.5
41	Air—Primary air to furnaces	" water	15.1	14.9
	Average Drafts			
42	In furnaces	" water	0.03	0.005
43	In 4th pass of boiler	"	0.76	0.38
44	At economizer outlets	"	2.2	1.2
45	At fan inlets	"	9.3	5.6

	Average Temperatures			
46	Steam saturated	°F	435.5	435.8
47	" superheated	"	625.5	625.9
48	" superheat	"	194.4	194.2
49	Water—Water to boiler feed pump	"	211.5	147.5
50	Water—Economizer outlets	"	295.3	238.5
51	Gases—In 4th pass of boiler	"	584.3	553.1
52	Gases—Economizer outlets	"	316.3	245.2
	Products of Combustion			
53	At boiler outlets—CO_2	per cent	14.5	15.6
54	CO	"	0.0	0.0
55	O	"	4.5	3.2
56	Dry gases per lb. coal	Lb.	14.11	13.23
	Hourly Quantities			
57	Coal burned in furnaces	Lb.	27,950	23,250
58	Coal burned per burner	"	1,551	1,292
59	Actual Water	"	314,000	258,500
60	" " per lb. of coal	"	11.25	11.11
61	Factor of evaporation		1.087	1.144
62	Equivalent evaporation	Lb.	342,000	296,000
63	" " per lb of coal		12.22	12.72
64	Average boiler h.p. developed	h.p.	9,920	8,580
65	Per cent builders rating		224	194
	Efficiencies			
66	Of boilers and superheaters	per cent	82.9	85.8
67	Of boiler plant	"	89.4	92.9

The Performance of the Main Turbine Generator

The performance of the main turbine generator is stated in detail for tests OT and ST, in table D-7.

The average generation during test OT was 26.790 K.W. and the variation in load was between a maximum of 35,453 KW. and a minimum of 18,227 KW.

The turbine with its condenser operated under unfavorable conditions in that the super-heat at the turbine throttle averaged on test OT 197.6 deg. as against 220 deg. specified in the guarantees. Furthermore, the inlet circulating water had an average temperature of 82.6 deg., which high temperature should be present for only approximately two per cent of the time during a year's operation. As a matter of fact, the circulating water temperature on July 7th, went as high as 91.5 deg.

Otherwise, during test OT the plant was run under normal operating conditions and approximately 10 84 per cent of the total superheated steam supplied to the turbine was bled to the stage heaters or was supplied to the turbine glands. During test ST, however, the stage heaters were practically cut out of service, with the result that only 3.8 per cent of the superheated steam supplied to the turbine was bled to the stage heaters or supplied to the glands.

Correction for the deviations of vacuum, pressure and superheat from these specified for the guaranteed or normal operating conditions, of one inch absolute vacuum, 350 lb. pressure and 220 deg. super-heat, shows on test ST, during which the bleeding was practically eliminated, that the corrected net water rate, including steam fed to the glands, would be approximately 9.96 lb. per K.W.H. generated, as against the guaranteed water rate for these conditions, of 10.12 lb. per K.W.H. It is indicated by this that the turbine bettered its guaranteed performance by approximately 1.58 per cent.

The turbine generator was purchased from the General Electric Company with a stated capacity of 30,000 KW at 80 per cent power factor, equivalent

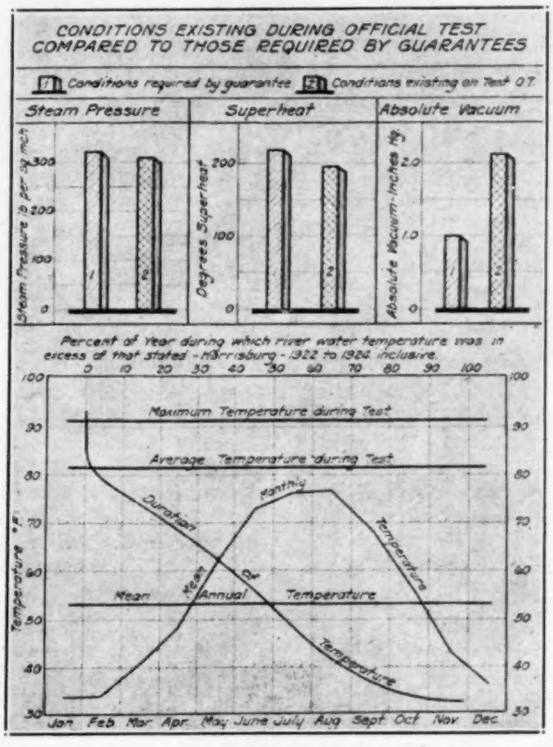

CONDITIONS EXISTING DURING OFFICIAL TEST COMPARED TO THOSE REQUIRED BY GUARANTEES
Conditions required by guarantee
Conditions existing on Test O.T.
Steam Pressure
Superheat
Absolute Vacuum
Steam Pressure in lbs. per sq. inch
Degrees Superheat
Absolute Vacuum-Inches Hg.
Percent of Year during which river water temperature was in excess of that stated - Harrisburg - 1922 to 1924 inclusive.
Maximum Temperature during Test
Average Temperature during Test
Monthly Mean Temperature
Duration of Mean Annual Temperature
Temperature °F
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.

FIG. 6 and 7

to 37,500 K.V.A. During test OT the turbine was loaded up for a period of two hours and ten minutes on July 9th and for a period of one hour on July 10th, in order to determine its capacity and the heating which occurred with that capacity. On July 9th, during the two hour period, the load varied between

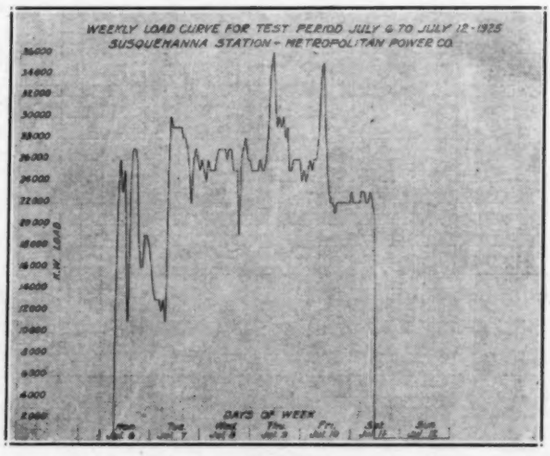


FIG. 8.

34,500 K.W. and 35,500 K.W. with a maximum hour's generation of 35,453 K.W.H. On July 10th, the output for the hour during which the capacity run was made was 34,500 K.W.H. and with a corresponding power factor of approximately 89 per cent

imposing a load of 39,800 K.V.A. upon the generator which was in excess of the 37,500 K.V.A. specified within the guarantees.

Under these conditions the maximum temperature shown by the thermo-couples located within the armature coils was 76 deg. cent. on July 9th and 77 deg. cent. on July 10th. The temperature rise above that of the intake air to the turbine was 51 deg. cent. on July 9th and 50 deg. cent. on July 10th, as against the 60 deg. cent. rise allowed within the specifications.

From the results obtained, it appears that the plant can be rated at 35,000 KW at 80 per cent power factor.

TABLE D-7

PERFORMANCE OF MAIN TURBINE GENERATOR

Line		Unit	Test OT	Test ST
	Quantities			
68	Duration of Test	Hr.	72.167	22.517
69	Energy generated	Kw. hr.	1,932,294	499,096
70	Voltage — Generator leads	Volts	13,800	13,820
71	Power factor calculated	Per cent	91.9	87.6
	Pressures			
72	Steam-turbine throttle	lb/sq. in.	318.5	323.3
73	Steam-turbine primary nozzle	"	306.1	272.8
74	Steam-turbine Secondary nozzle	"	200.5	155.7
	Temperatures			
75	Steam—At turbine throttle	°F	624.8	625.6
76	—Superheat	"	197.6	197.1
	Hourly Quantities			
77	Energy generated	Kw. hr.	26,790	22,200
78	Steam to turbine	Lb.	300,000	247,500
79	Condensate from condenser	"	258,000	238,200
80	Total water rate of turbine	lb/kw. hr.	11.20	11.15
81	Water rate of turbine less bleeding of glands (c)	"	9.97	10.73
82	Total steam to turbine corrected for vacuum, pressure and superheat variations from those stipulated	Lb.	273,500	228,000
83	Corrected total water rate	lb/kw. hr.	10.20	10.25
84	Corrected net water rate	"		9.85
85	Guaranteed water rate	"	9.93	10.12
	Efficiency			
86	Thermal	Per cent	24.2	24.5

Condenser Performance

The performance of the condenser is stated in detail in table D-8.

The condenser operated during both the official test and test ST under unfavorable conditions inasmuch as the temperature of the inlet circulating water averaged 82.6 deg. F. during test OT and 81.6 deg. F. during test ST. In fact the temperature of the inlet circulating water during test OT reached a maximum of 91.5 deg. As has previously been shown the inlet circulating water temperature prevailing during test OT and test ST, should not, in an average year, be present for more than two per cent of the time, or approximately seven days. Fig. 7 shows the duration of river water temperatures for the years 1922 to 1924 inclusive.

Total Plant Results

The performance of the plant as a whole is stated in detail in Table D-10.

In the official test the plant produced a K.W.H. of output for 1.11 lb. of coal, while under test ST, 1.121 lb. of coal were required.

The results achieved during these tests were excellent when it is considered that the plant operated with an inlet circulating water temperature which was excessively high, and also, that steam was furnished to the turbine at a super-heat of more than 10 per cent below that called for by the guarantees.

If the deviations from specified vacuum, pressure and superheat under which the turbine was guaranteed were corrected for, the coal rate of the Susquehanna Station during test OT would have been reduced from 1.11 lb. of coal to 1.013 lb of coal per K.W.H. of output and the B.T.U. per K.W.H. would have been reduced from 15,900 to 14,510. Correspondingly, on test ST the lb. of coal per K.W.H. of plant output would have been reduced from 1.121 to 1.032 and the B.T.U. per K.W.H. of plant output from 16,100 to 14,850.

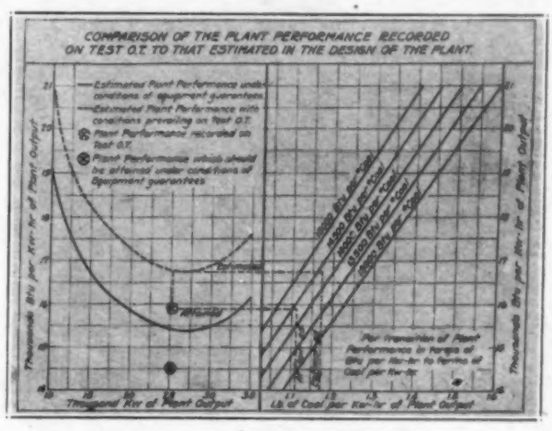

COMPARISON OF THE PLANT PERFORMANCE RECORDED ON TEST O.T. TO THAT ESTIMATED IN THE DESIGN OF THE PLANT.
Thousands Btu per Kw-hr. of Plant Output
Thousand Kw. of Plant Output
Lb. of Coal per Kw-hr. of Plant Output

FIG. 9.

TABLE D-8

CONDENSER PERFORMANCE

Line		Unit	Test OT	Test ST
	Pressures			
87	Barometer	Hg.	29.87	29.79
88	Vacuum (By mercury Column)	"	27.75	27.86
89	Presssure—absolute	"	2.12	1.93
	Temperatures			
90	Water Circ. inlet	°F.	82.6	81.6
91	" discharge	"	91.3	89.0
92	Water—Condensate	"	100.5	96.4
	Results			
93	Steam condensed per hr.	Lb.	268,000	238,200
94	Quantity of condensing water per hr. (c)	"	31,900,000	33,450,000
95	Quantity of condensing water (c)	g.p.m.	63,800	66,800
96	Heat transfer per ° diff. temp. per sq. ft. per hr.	B.t.u./hr.	483	491

Figure 8 shows the load on the plant during the week of the test, and figures 9 and 10 show test

performance plotted against the designer's expected results.

After checking each individual piece of equipment it was found that certain equipment exceeded manufacturer's guarantees, and this is the reason that the operating results are better than those expected by the designers.

The operating figures for the past nine months, during which the plant has been in operation, show that the plant performance every month has been

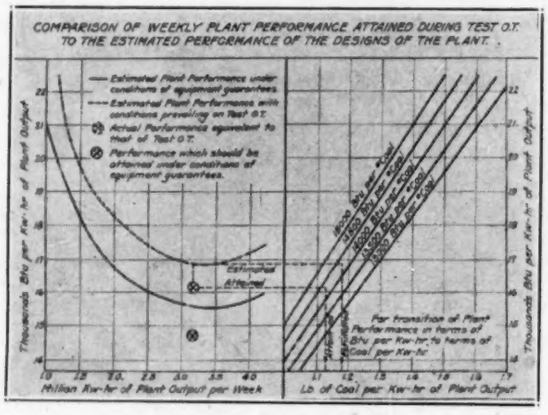

COMPARISON OF WEEKLY PLANT PERFORMANCE ATTAINED DURING TEST O.T. TO THE ESTIMATED PERFORMANCE OF THE DESIGNS OF THE PLANT.
Estimated Plant Performance under conditions of equipment guarantees.
Estimated Plant Performance with conditions prevailing on Test O.T.
Actual Performance equivalent to that of Test O.T.
Performance which should be attained under conditions of equipment guarantees.
Estimated Attained
Thousands Btu per Kw-hr of Plant Output
Million Kw-hr of Plant Output per Week
Lb. of Coal per Kw-hr of Plant Output
For transition of Plant Performance in terms of Btu per Kw-hr to terms of Coal per Kw-hr

FIG. 10.

better than the anticipated performance. Even though the plant is shut down at noon every Saturday and started again every Monday morning and the boilers banked at night, the B.T.U. per net K.W H. output has been as follows:

February	17,991	June	19,181
March	16,615	July	17,151
April	17,072	August	16,887
May	17,678	September	16,893
		October	16,545

The station load factor for the month of June was only 33.9 per cent and for the month of May 37.3 per cent.

TABLE D-10
GENERAL PLANT DATA AND RESULTS

Line		Unit	Test OT	Test ST
97	Duration of Test	Hr.	72.167	22.517
98	Kw. hr. generated	Kw. hr.	1,932,294	499,096
99	" " output	"	1,815,861	467,506
100	" " to auxiliaries	"	116,884	32,488
101	" " to coal house	"	14,715	3,630
102	Coal consumed	Lb.	2,016,292	524,115
103	Total water evaporated	"	22,658,753	5,820,090
104	Average kw. generated	Kw.	26,790	22,200
105	" " output	"	25,150	20,800
106	Volts—generator leads	Volts	13,800	13,820
107	Current per phase	Amperes	1,220	1,060
108	Average power factor —computed	Per cent	91.9	78.5
109	B.t.u. per lb. coal	B.t.u.	14,324	14,385
110	Deviation from specified vacuum, pressure and superheat in turbine guarantee	Per cent	-8.9	-7.8
	As Recorded by Test			
111	Lb. coal per kw. hr. generated	Lb.	1.042	1.051
112	Lb. coal per kw. hr. output	"	1.110	1.121
113	B.t.u. per kw. hr. output	B.t.u.	15,900	16,100
114	Water evaporated per lb. coal	Lb.	11.25	11.11
115	Efficiency boiler plant	Per cent	89.4	92.9
116	Water used per kw. hr. output	Lb.	12.50	12.45
117	% auxiliaries to plant output	Per cent	6.43	6.94
118	% coal house energy to plant output	"	0.81	0.78
119	% saturated to total steam	"	2.94	2.78
120	% makeup to total steam	"	1.10	1.22
	Corrected for deviation of vacuum pressure and superheat from turbine guarantees			
121	Water used per kw. hr. output	Lb.	11.40	11.49
122	Lb. coal per kw. hr. output	"	1.013	1.032
123	B.t.u. per kw. hr. output	B.t.u.	14,510	14,850

Items of Interest

The space at the Iron and Steel Exposition, which will be held June 7 to 10, inclusive, Hotel Sherman, Chicago, Illinois, was all sold practically 10 days after the applications for space were mailed.

The Iron and Steel Exposition this year, the Convention and all of the social activities will be under one roof, The Hotel Sherman, Chicago, Ill.

The April Issue of the Iron and Steel Engineer contains one of the best papers in connection with Strip Mills that has ever appeared in print. This article was contributed by Mr. Noble Jones, Works Manager, West Leechburg Steel Company, West Leechburg, Pa.

Mr. Jones started out early in life with the Cramps Shipbuilding Company, Philadelphia, as an electrical apprentice. Later on, he became associated with the Maryland Steel Company, Sparrows Point, Md., as assistant superintendent of the electrical department. Mr. Jones later accepted the position of electrical superintendent with the Sharon Steel Hoop Company, and was with this company for practically twenty years. In addition to executing the duties of the electric superintendent, he was made master mechanic and later was made superintendent of the Sharon Steel Hoop Company. He is now associated with the West Leechburg Steel Company as Works Manager.

The May Issue of the Iron and Steel Engineer will contain the minutes of the Safety Congress held March 10, at Pittsburgh. Practically the entire Steel Industry was represented at this Conference and the

transactions will be valuable additions to the Association of Iron and Steel Electrical Engineers' files.

The June Issue of the Iron and Steel Engineer will contain all of the Convention papers to be presented before the A. I. & S. E. E. at Chicago, June 7 to 10, inclusive. The official program and all of the items of interest in connection with the Convention will appear in this issue.

The technical program will be of interest to every electrical engineer and superintendent in the Iron and Steel Industry. One of the feature days will be "Electrical Transportation."

Another problem which will receive major attention from the Steel Industry will be the subject "Standardization of Mill Type Motors." The standardization committee has already performed a task and achieved results that was thought practically impossible three months ago. This problem of standardization is of vital interest to the Iron and Steel Industry and since practically every steel plant in the United States has voiced its approval of this movement, standardization should become a possibility in a very short time. The electrical manufacturers are to be congratulated on the co-operation they have extended to the Standardization Committee.

The Electrical Heat Committee this year has a program which should and will be of interest to the engineers in Industry who have heating problems to solve.

The Combustion Committee will present one of the most interesting subjects for discussion, since they have become a division of the A. I. & S. E. E. Every executive in the Iron and Steel Industry and every combustion engineer is interested in the subject of Refractories. Blast Furnace Linings, Open Hearth Roof Construction, Heating Furnaces and Boilers will all be discussed.

Mr. M. J. Conway, Combustion Engineer of the Steubenville Plant of the Wheeling Steel Corporation will present a paper that will be of interest to every rolling mill superintendent in the United States. Mr. Conway will describe the additions to rolling mills at the Steubenville plant of the Wheeling Steel Corporation. His description will cover the auxiliaries to mills, such as Boiler Plant Equipment, Gas Producers, Soaking Pits, etc.

The author's paper will also include a description of the 35" Blooming Mill as well as the 19" Continuous Sheet Bar Mill. The detailed description of the Nordberg Reversing Uniflow Engine and operating control, also the results of tests on the Nordberg Engines giving the steam consumption per ton of steel rolled will receive attention from every steam and electrical engineer in the United States.

The Chicago Section in addition to having charge of practically all of the activities of the Convention will provide an inspection trip for those who attend the Convention. The inspection trip will cover one of the steel plants in the immediate vicinity of Chicago.

The July Issue of the Iron and Steel Engineer will contain a paper by Mr. L. W. Egan, covering "Electrification and Simplification—Their Effect Upon the Foundries' Future." The Foundry Industry is the oldest of the metal working industries known to civilization and dates back to the dawn of history. Castings were made centuries ago that were the equal if not superior to some of our best castings made today. Mr. Egan's paper deals with continuous foundries where the moulds are made and poured and shaken out while on roller conveyors without a mould being set on the floor. Continuous sand handling and sand conditioing systems where the sand is handled continuously and completely conditioned in the process with all of the operations being performed mechanically. Moulding sands and facing sands with their effect upon rejections are given special attention and study since the great necessity for a stabilized sand control is so beneficial for successful foundry practice. The author also treats upon the subject of green sand moulds without facings for steel castings.

Five different methods of milling or conditioning sands are described, including a description of the new bar type continuous conditioner which may revolutionize sand conditioning in steel foundries. The three major types of moulding machines which incorporate the electric moulding machine and the sand slinger, and flask fillers are described in this paper.

The melting of steel, grey iron and non-ferrous metals in the electric furnace is very broadly discussed. Most interesting data is given in connection with the melting of grey iron. The author portrays the evolution of electric melting from the former multitude of furnace types both in ferrous and non ferrous metals to the very few types now in successful use. Various type of furnaces are discussed. Electric annealing and core baking has also been given considerable thought. Special attention has been given "Simplification." Also how to avoid the enormous wastes in Sand, Labor and Upkeep.

The July Issue will also contain a complete story in connection with suspended arches. This article will be an exhaustive study of suspended arches and will be contributed by Mr. Louis Ellman, Vice President, The M. H. Detrick Company, Chicago, Illinois. Suspended Arches, showing their application to all types of Boilers, fired with Stokers, Powdered Coal and Blast Furnace Gas, also the application of suspended arches to all forms of Heating Furnaces and Soaking Pit Covers will be discussed. The author will also deal with the application of suspended walls for boilers. This article will practically be a reference and a guide for the fuel and combustion engineers in Industry.

The following applications have been received for membership: Mr. James A. Faulkner, Manager, J. A. Faulkner Refractories Company, Youngstown, Ohio; Mr. W. L. Sprengle, District Manager, Automatic Reclosing Circuit Breaker Company, Columbus, Ohio; Mr. Edward T. Mug, Salesman, Crocker Wheeler Company, Pittsburgh, Pa.; Mr. W. D. Smoot, Electricial Engineer, The Collier Construction Company, Cleveland, Ohio; Mr. G. R. Carroll, Asst. Electrical Superintendent, Jones & Laughlin Steel Corporation, Woodlawn, Pa.; Henry J. Walters, Asst. Elect. Supt, Jones & Laughlin Steel Corp., South Side Works, Pittsburgh, Pa.; Mr. H. J. Saville, Sales Engineer, W. F. Hessel Company, New York, N. Y.; Mr. Gordon R. Van Aken, Chief Elect., The Universal Portland Cement Company, Buffington, Ind.; Mr. Frank H. Gill, Salesman, The Cleveland Crane & Engineering Company, Wickliffe, Ohio;

Mr. H. A. Hallead, Sales Engineer, Kohlenite Products Company, Inc., New York, N. Y.; Mr. W. L. McCaslin, Chief Electrician, Armour & Company, Chicago, Ill.; Mr. J. W. Sheffer, Asst. Engr., American Car & Foundry Company, New York, N. Y.; Mr. J. C. Murray, Asst. Supt., Blast Furnaces, Jones & Laughlin Steel Corporation, Pittsburgh, Pa.; Mr. T. M. Salisbury, Sales Engineer, General Electric Company, Birmingham, Ala.; Mr. D. S. Borland, Sales Engineer, Crocker Wheeler Company, Ampere, N. J.; Mr. H. R. Zimmerman, Supt. Power, American Sheet & Tin Plate Company, Gary Sheet Mill, Gary, Ind.; Harry G. Hague, Supt. Elect. Dept., American Sheet & Tin Plate Company, Gary, Ind.; William C. Fork, Asst. Supt., Acme Steel Company, Riverdale, Ill.; Walter Palmer Gavit, Power Engineer, Dwight P. Robinson & Company, Inc., New York, N. Y.; Walter H. Haas, Sales & Service, The Pyle National Company, Chicago, Ill.; Mr. F. J. Evans, Dist. Engr., Southern Industrial Engineering Company, Birmingham, Ala.; J. C. Hayes, Mechanical Engineer, Freyn Engineering Company, Chicago, Ill.; Mr. William J. Dreiss, Industrial Control Specialist, General Electric Company, Philadelphia, Pa.; Arthur A. Van Pelt, Dist. Rep., SKF Industries, Inc., West Waldheim Road, Aspinwall, Pittsburgh, Pa.; Chas. R. Crater, Elec. Supt. and Master Mech., Jas. B. Clow & Sons, Newcomerstown, Ohio; K. Tachibana, Elec. Engr., The Imperial Steel Works, Yawata, Japan.

John V. Calhoun, formerly Engineer of Furnace Construction with Combustion Engineering Corporation, New York City, has taken up his new duties as Sales Manager with Harold E Trent, manufacturer of Electrical Heating and Temperature Control Appliances, Philadelphia, Pa.

Dwight G. Phelps was elected Vice-President in charge of Sales of The Johns-Pratt Company at a recent meeting of the Directors of this firm.

For many years, Mr. Phelps has been Sales Manager of the Colt's Patent Fire Arms Mfg. Co. of which The Johns-Pratt Company is an important division.

The business of The Johns-Pratt Company, founded in 1886, was first confined to the manufacture of Vulcabeston compound asbestos valve discs, but was soon expanded to include various forms of sheet and wick packings. With the invention of the Noark cartridge enclosed fuse, The Johns-Pratt Company became the pioneer makers of this type of electrical protective device, and developed many other electrical protective devices, prominent among them being the Noark Meter Service System of enclosed meter entrance switch boxes. In recent years the production of molded materials has also been an important feature of this business.

A change in the computation of the horsepower ratings of Micarta gears, based on the use of a fiber stress figure of 6,000 pounds in place of 5,000 pounds, previously used, is fully described in a new publication recently released by the Westinghouse Electric and Manufacturing Company.

This publication C-1579-D is the most complete ever issued on this subject and the excellent tables contained in it will assist the gear manufacturer in calculations on Micarti gears. Examples of how to calculate the horsepower rating; tables giving the preferred pitch, the values of the constants used, gear data, and horsepower ratings at various pitches are included.

Micarta, its qualities and its advantages in gears and pinions is described in this illustrated circular which may be obtained from any of the district offices or from the publicity department at East Pittsburgh, Pa.

THE EFFECT OF PHOSPHORUS ON THE RESISTANCE OF LOW CARBON STEEL TO REPEATED ALTERNATING STRESSES

Bulletin Number 25 Mining and Metallurgical Investigations, Carnegie Institute of Technology, Pittsburgh, Pa.

The element phosphorus is the traditional bete noir and "poison" of steel. It would be out of place here to attempt to trace the origin and development of this tradition, and it is equally inappropriate for science to accept a tradition, but it is the privilege of science to acknowledge a tradition of this kind and search it for truth and accuracy.

Metallurgists have devoted considerable attention to the elements phosphorus and sulphur in steel and find that some of the traditions of the evil effects of these elements are unfounded. They are now engaged in a study of the effects of these elements, in soft steels, those with a carbon content of less than 0.20 per cent. They find that the phosphorus gives some beneficial effects and, in most instances, they have not been able to detect harmful effects which tradition assigns to the element. It is believed that the results reported in this bulletin will help to establish some of the facts and fit in with work which is being carried on by other investigators.

This bulletin is a record of a study of the influence of phosphorus on the fatigue life of low-carbon steels. The work was carried out by a Research Fellow in the Department of Mining and Metallurgy, Carnegie Institute of Technology, under the co-operative agreement which exists between the Institute and the United States Bureau of Mines. The results were presented as a thesis for a Master's Degree in Metallurgy, and it is published in bulletin form and made available for distribution in order that a permanent record of the work be established and made available for all who are interested in the problem.

Briefly, the findings are these: For the addition of phosphorus (from 0.010 to 0.125 per cent) to low carbon steel(containing less than 0.15 per cent carbon), it may be said from this investigation and the results of others that (1) phosphorus increases the endurance of the steel against repeated alternating stresses; (2) it increases the hardness, ultimate strength and elastic limit; (3) it has no particularly bad effect on the resistance to shock or vibratory strain; and (4) it increases the resistance to corrosion and abrasion and has no well-defined effect on durability.

The McKinney Steel Company a few months ago purchased a 9,000 horsepower synchronous G. E. Motor for driving a Morgan continuous billet mill. This is the highest continuous horsepower rating of any industrial motor in the world.

The elimination of the confusion caused by thirty wire and sheet metal gage systems now in use in this country is to be brought about as the result of a conference held on March 18, 1926, in the Engineering Societies Building, New York City, and attended by representatives of twenty-five organizations interested in all phases of the subject, which includes wires, sheets and tubes of metals of all kinds.

Unanimous decision was reached that the confusion in the purchase and sale, and in the use of these products, brought about by the existence side by side of the numerous conflicting gage systems, has become intolerable, and that industrial practice should be unified in a simple consistent plan. The detailed technical work will be in the hands of a sectional committee broadly representing all interested industrial groups and working under the auspices of the American Engineering Standard Committee.

The trend of opinion at the conference strongly favored the elimination of all gage numbers and the use of a simple system of designating sizes in decimals of an inch. The decision, however, on the exact form of the solution was left to the sectional committee, the scope of whose work was outlined as follows:

> "The standardization of a method of designating the diameter of metal and metal alloy wire, the thickness of metals and metal alloys in sheet, plate and strip form and wall thickness of tubing, piping and casing made of these materials; and the establishment of a standard series, or standard series, of nominal sizes and of tolerances for wires, sheets, plates and strips."

The Westinghouse Electric and Manufacturing Company has just released leaflet 25403 describing the design and engineering specifications of their types R and RA disconnecting switches. This leaflet contains several illustrations of these disconnecting switches, and also a table showing the outdoor shell-type insulator assembly ratings.

This leaflet may be obtained from any of the district offices of the Westinghouse Company or from the Department of Publicity at East Pittsburgh, Pa.

"Some Developments in the Electrical Industry During 1925," by John Liston, has been issued as a 62-page publication (GEA-335) by the General Electric Company, Schenectady, N. Y. The review covers each phase of electrical application and its outstanding developments during the past year. It is divided into numerous sections, contains 103 illustrations and an index.

The largest Scherbius drive ever made will be installed by the McKinney Steel Company as part of the equipment for a new 12-inch Morgan merchant mill at Cleveland. The New Scherbius drive will include a mill type motor rated 5610/4500/3370 horsepower, 156/125/93.6r.p.m. at 6600 volts with a regulating set and ohmic drop exciter.

Four 800-horsepower, 600-volt motors with complete control equipment will also be installed for driving the mill. All the electrical equipment will be made by the General Electric Company.

Copper-tungsten electrode, a development which is expected to prove of great value in the fabrication of metals, is now available for use in manufacturing. This announcement is made by the General Electric Company who evolved the new electrode.

One of the limiting features in many resistance or spot welding operations has always been the copper electrode used, the pure copper not being hard enough when used under the high pressures at high currents common to this type of welding. Usually, after a few welds are made, the surface of the copper electrode in contact with the weld becomes hot enough to anneal the copper, thus making it very soft. As a result, the copper tip rolls and mushrooms over the edges, giving a large spot weld which changes the current density and, consequently, the quality of the weld.

Copper-tungsten, as its name indicates, is a mixture of two metals, one a good electrical conductor and the other very hard. The alloy has a hardness of 225 (Brinnell) as compared with 82 for hard copper and 30 for soft copper. The compressive strength of the copper-tungsten is 208,000 pounds per square inch as against 58,000 pounds per square inch for hard copper. The tensile strength is 56,350 pounds per square inch compared with 30,000 pounds for soft copper and 50,000 to 70,000 pounds for hard drawn copper.

Copper-tungsten does not anneal at red heat. Thus there is no soft surface metal to roll or mushroom over when used in resistance welding. It has not been found necessary to form the entire electrode point or die of copper-tungsten, but rather to use inserts of this alloy by any one of a number of methods, such as forcing an oversized piece in a hole in the die, brazing a block in the wearing surface or placing pieces in a mold and casting the die around them. The remainder of the die is made of copper as before.

In view of the higher first cost of copper-tungsten, its chief value is expected to be in special applications. It is particularly adapted for use under severe conditions where copper will not stand up, such as hot upsetting rivets electrically, and in facings for clamps for rod welding, split dies for welding steel spokes to both rim and hub of steel wheels and in many other applications where copper cannot be used because of its softness. In such instances, without the use of resitance welding which is now made feasible, it would be necessary to adopt other and more expensive methods of fabrication.

The durability of the new alloy is shown by a recent test, where the number of welds made with one dressing of a copper die averaged ten, while the first test using copper-tungsten inserts gave more than 1,000 welds with the die still in good condition at the end of the test. Other tests showed better results. It is therefore expected that the cost of changing the old copper electrodes and redressing them will more than pay for the larger first expenditure for copper-tungsten.

Delivered as a talk before a meeting of the operators of the Minnesota Power & Light System.

The installation and maintenance of Oil Circuit Breakers is of interest to all Electrical Superintendents.

An oil circuit breaker is the valve for the outlet or intake of generated electrical energy, and if not properly installed or maintained, stops the produc-

tion of power or taking in of power. It is, therefore, extremely essential that it be properly installed, and after installation that it receive proper care, just the same as any main steam valve or water valve.

Oil circuit breakers when operating under circuit must open many times the normal generating capacity of a system, due to the fact that when a short circuit occurs on a system the current value rises greatly and this higher current value must be broken at the time of trouble. Therefore, the term "interrupting capacity." I repeat, therefore, that installation and maintenance of an oil circuit breaker is just as important, or more so than a good many other pieces of electrical apparatus.

I am, therefore, going to give below some points to be borne in mind when an oil circuit breaker is being installed and afterwards some points on how the breaker should be maintained after installation.

Installation

1. With all oil circuit breakers shipped by manufacturers there are given complete instructions for installation of breaker. Follow these instructions carefully and to the letter.

2. After installation carefully check all moving parts to see that they function properly and freely, and that all bearings run free.

3. Check studs and be sure that they are properly tightened in place.

4. Inspect contacts for alignment to make sure that they all seat properly, that they do not bind, and that all contacts make and break at the same instant.

5. Be sure that tanks are full of proper oil and filled to the proper level, and that the oil is clean and dry.

6. Oil all moving parts on the mechanism thoroughly before attempting to put the breaker in service.

7. The breaker should now be ready for trial. Always try the breaker by hand first whether manual or electrical, and be sure that the breaker is dead before this trial is made.

8. If breaker is electrically operated and all of the above points prove satisfactory and breaker operates satisfactorily by hand, then try electrical operation with the breaker still disconnected from the line. Do not try electrical operation with the tanks off. The tanks should be in place so that the additional effect of the contacts traveling through the oil is obtained. If trial is made with tanks off there is also some danger of injury to the breaker, due to the lack of cushion caused by the contacts traveling in oil.

9. You are now ready to make connections to the breaker, and when these connections are made be sure that they are tight and of ample size, otherwise if this is not the case heating may develop in the breaker and the breaker be held responsible for this heating, when as a matter of fact, the trouble is in the connections and being communicated from them to the breaker.

10. Be sure the breaker frame is thoroughly grounded.

11. The breaker is now ready for service and should go on the line without any further trouble, provided everything has been taken care of as outlined above.

A Few Don'ts

1. Don't install a breaker in a dead air pocket. All electrical apparatus must have changing air, and a breaker is a piece of electrical apparatus. I have seen many cases where breakers installed in dead air pockets have unduly heated simply due to the fact that there was no changing air, with the resultant fact that the heat continually built upon pyramided, and the breaker was held at fault when simply a small circulation of air was all that was needed.

2. Don't guess. Your guess may be wrong and cause a shutdown, which of course, means a loss of revenue and a dissatisfied customer. If you do not know, find some one that does or look up your instructions on that particular breaker and find out.

3. Don't expect an indoor breaker to withstand the elements such as installing in a wet room or by a window and then leave the window open during storms.

4. Don't install out of alignment. If a breaker is not properly aligned at time of installation some time when that breaker should operate automatically you may get a binding of parts when there is the greatest need for breaker to open.

5. Don't install a breaker too small in ampere carrying or in interrupting capacity and expect it to function properly on your system. In the first case you will get heating; in the second case trouble will develop in case the breaker is called upon to operate under short circuit.

Inspection

After an oil circuit breaker is in operation see that this breaker receives proper and periodical inspection. Every breaker should be inspected at regular intervals about every three months. It should also receive inspection after it has opened under a severe short circuit. Some companies are even going so far on inspection that a breaker is inspected after every operation even under normal conditions. This latter applies to stations in the Super-Power Class.

A regular inspection should include the following:

A. Cleaning of all parts including oil.

B. The oiling of all moving parts with particular reference to the mechanisms, whether these mechanisms are solenoid or manual.

C. Check contacts and make sure that they seat properly, clean and realign if necessary.

D. See that all connections to and from the breaker are tight and are not causing undue heating.

E. Check all mechanisms whether manually or electrically operated and make sure that they operate properly. In checking mechanisms, this is to include the checking of trip coils so that in case breaker is called upon to operate automatically the trip coils are in proper condition to open breaker.

F. Check the ground connection to the breaker.

G. All the above under the subject of inspection is on the basis of a periodical inspection. If a severe short has been taken by a breaker it should be inspected complete as soon as possible thereafter. In making the inspection after the breaker has opened a short circuit, also in the course of regular inspection, look for weakened or broken parts and replace if necessary.

It is advisable to have a complete supply of spare parts on hand for those parts of the breakers,

such as contacts which are most apt to burn out or give trouble.

It would seem from the above that I am possibly classing an oil circuit breaker as a piece of apparatus that needs continual or extra care. I do not wish this idea to be conveyed at all. What I do wish to convey is that an oil circuit breaker is apt to be looked upon as a piece of apparatus to be installed and forgotten, due to the fact that there are no rotating parts to call the operator's attention to the fact that it is a piece of electrical apparatus. Therefore, an oil circuit breaker, the same as any other piece of electrical apparatus should receive ordinary care, so that the best results may be obtained from it. We would not think of allowing a turbine to run year in and year out without periodical inspection, and at least putting some oil in the bearings. If we give the same care to an oil circuit breaker that we would ordinarily give to a piece of rotating apparatus, I am sure that we will find that the oil circuit breaker will be very grateful, and in turn give us excellent service, and operate properly as the valve for the sending out or taking on of power.

Mr. O. L. Holcombe has been appointed District Manager for the Philadelphia Office to represent The Clark Controller Company of Cleveland, Ohio.

Mr. Holcombe will open district offices in the Atlantic Building, Philadelphia.

ARTIFICIAL ILLUMINATION IN FOUNDRIES

The economic advantages of good lighting in industrial plants are now generally recognized by factory executives. A summary of the gains to be expected from good lighting serves to refresh the memory of the reader and shows why the proper method of lighting foundries is important in detail. The advantages of good lighting in Foundries are tabulated herewith:

1) Increased production—5-15%.
2) Decreased spoilage—5-15%.
3) Reduction of seconds, or poor product—5-15%
4) Reduced accidents—25%.
5) Reduced labor turnover (indefinite).
6) Improved morale (indefinite).

The cost of the lighting which causes these advantages is approximately 1% of the payroll.

The foundry is one of the most difficult industrial buildings to illuminate both from the standpoint of daylight and artificial light. The chief obstacle encountered is maintenance. The windows, skylights, reflectors and lamps quickly become coated with dust which, because of its character, bakes on so that it is hard to remove. The walls, ceilings, columns, girders and all working surfaces take on a dark neutral gray color, so that very little light is diffusely reflected and direct light from the windows or the reflectors must be relied upon entirely for illumination. Ordinarily, the light comes from several comparatively small sources with a dark background and surroundings which are ideal conditions for glare and sharp shadows. These unfavorable conditions for lighting are usually further accentuated by under-illumination. Objects are seen by light reflected from them. The quantity of illumination which might suffice in a printing plant where black ink on white paper having excellent reflection and contrast constitutes the work, would be insufficient in a foundry where the molds reflect very little light and there is practically no contrast It is a generally mistaken idea that because the work done in a foundry is of a more or less rough nature and does not require the discrimination of fine detail, a low level of illumination is sufficient. The accident hazard in foundries, together with the low reflection properties and low contrast of the material worked on, makes a relatively high illumination intensity desirable.

Intensity of Illumination

It is a well-known principle that highly satisfactory vision can be obtained if an illumination of approximately 2 foot candles is reflected from the work into the eye. For this ideal condition to be obtained in a foundry, an illumination in excess of two foot candles must be incident on the work. The two foot candles of illumination must be increased to compensate for the light obsorbed by the molds. Thus the light delivered by the reflectors must be $\frac{2}{0.4} = 5$ foot candles. The factor 0.4 represents the reflection factor of the material worked on. For this 5 foot candles to be maintained between cleaning and relamping intervals it must be further increased by an amount equal to the lamp depreciation due to ageing and further increased again by an amount representing the dust and dirt depreciation of the reflector and the lamp. The illumination of 5 foot candles then becomes $\frac{5}{0.8 \times 0.6} = 10$ foot candles. The factor 0.8 represents the lamp depreciation due to ageing and the factor 0.6 represents the depreciation due to dust and dirt on the lamp and reflector. It is the failure to take these various losses into account when making the original lighting installation that is the cause of future dissatisfaction.

It is a conclusion from the above, therefore, that for general foundry practice, the minimum initial illumination on the work should be 10 foot candles if the workman is to receive the two foot candles necessary for good vision.

Maintenance

Not only is the general atmosphere of a foundry continually laden with fine dry dust, but when the molds are shaken out and the sand wet down at the end of the day, there are clouds of steam and dust thrown up into the building. This steam and dust has considerable velocity and when striking the surface of the lamps and reflectors forms a film which quickly bakes on the lamp and reflector and causes rapid depreciation of the lighting equipment.

Reflectors and lamps should be cleaned every four months if reasonable service is to be expected (a loss of light of not over 50% due to dust and dirt.)

When a new lighting installation is first placed in service, it is apt to be maintained for a time but after the newness or novelty has worn off, maintenance is very likely to become slack and it is a common occurrence to see foundry lighting installations that are only giving a small part of the illumination possible for the current consumed. If some one went home at night and left the entire lighting system burning all night, he would probably be discharged

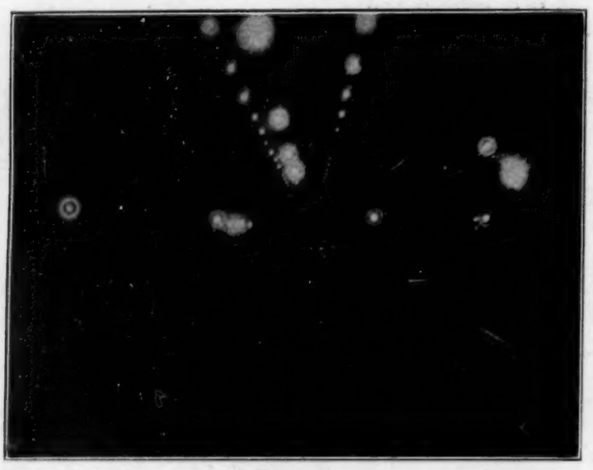
the next morning, but in effect, the waste of current due to poor maintenance is equivalent to burning the entire system all night every other night.

It is human nature to put off disagreeable tasks as long as possible, so if cleaning lighting equipment is made easy, it is more likely to be done.

Selection of Lighting Equipment

Foundries may be divided into two classes as far as lighting is concerned. First, those where the castings are small and are handled by manual labor, monorail or gantry crane. Second, those where the castings are heavy and are handled by an overhead crane.

Concentrating type glass reflectors with outer surfaces properly protected from dirt are invariably found to be the best equipment for this particular situation as exemplified in photographs.



Before

After

Unretouched photographs taken at the Hay Foundry, Newark, N. J., before and after lighting changes were made. The dark gloomy appearance of the Hay Foundry before lighting improvement was due to poor maintenance and incorrect type of reflectors. The total wattage of lamps after lighting changes were made was less than before. This is an excellent illustration of what can be accomplished with a good engineering layout and a good system of maintenance in a foundry.

In those foundries where small castings are made and where there is no overhead crane, the lighting units may be suspended relatively close to the floor and a wide or extensive type of light distribution can be employed to advantage. The best commercial reflector of this general type is the enameled steel dome reflector. This reflector should always be equipped with a bowl enameled lamp so as to give adequate shielding of the lamp filament. The candlepower values at the high angles to the vertical are effective in producing illumination on vertical surfaces. In order to obtain the required two foot candles reflected into the eye from the work, it will be necessary to use 200 watt bowl enameled Mazda lamps in the enameled steel dome reflectors spaced on 10 foot centers and mounted from ten to fifteen feet above the floor.

In foundries where the lighting units must be placed above the traveling crane, the distance between the floor and the lighting unit is excessive and if the steel dome reflector having a wide angle light distribution is used, a considerable portion of the available light will strike the upper side walls and will be absorbed. For this type of foundry, a reflector giving an intensive type of light distribution should be used.

The intensive type unit should be spaced on centers not to exceed the mounting height above the floor and three watts for each square foot of floor area should be installed so that the required two foot candles will be reflected from the work into the eye. Clear (not bowl enameled) lamps should be used in the intensive type reflectors. It is to be especially noted that no mentian has been made in the foregoing regarding the angle type or deep bowl steel type reflectors. In our opinion, neither of these reflectors have any application for foundry lighting. The angle type reflector is liable to produce excessive glare and defeats its purpose by making the eyes of the workers less sensitive so that the two foot candles already referred to is insufficient. The deep bowl steel reflector has its only application in local lighting as efficiency is sacrificed for shading effect. There is a popular impression that the deep bowl steel reflector gives an intensive type light distribution, but such is not the case and the reflector should never be used where an intensive type of distribution is necessary.

Any industrial lighting situation should be studied individually and equipment selected which is specially designed for specific application in that particular situation.

The Columbia Steel Company has recently placed orders for electrical equipment to drive a 40 in. blooming mill at the Butler Plant. This plant was formerly known as the Forged Steel Wheel Co., and has recently been acquired by the Columbia Steel Company. The blooming mill is now driven by a steam engine and the electrical equipment will consist of a 7000 hp. 50 to 120 rpm. d-c. reversing motor with a 6000 kw. flywheel motor generator set. The Westinghouse Electric & Mfg. Company, East Pittsburgh, will supply the electrical equipment.

The Carnegie Steel Company, Homestead Works, recently placed a contract with the Westinghouse Elec. & Mfg. Company for two 2000 hp. reversing mill motors with control and auxiliary equipment. These motors will be used in connection with the

large structural mills which are to be installed at the Homestead Plant.

The Sharon Steel Hoop Company at Sharon, Pa., has awarded the Crocker Wheeler Electric Manufacturing Company a contract covering two 800 H.P., 230 Volt Direct Current, 2.1 Variable Speed Motors. One 400 H.P. 230 Volt Direct Current 2.1 Variable Speed Motors. These motors will drive two 10" bar mills and a strip mill. Motors will be enclosed and will be equipped for forced air ventilation. Motors will be 35° capable of carrying 50% overload for two hours. The motors on the commutator end have been designed for vertical roller bearings. An order was also placed for the above company with the Crocker Wheeler Company, for One—Two Thousand KVA 80% Power Factor, 2200 Volt Three Phase 60 Cycle 514 RPM Synchronous Motor Generator Set.

The 1924 Yearly Transactions of the Association of Iron and Steel Electrical Engineers have been distributed to the paid up membership. These proceedings contain 928 pages of engineering data which is of direct interest to the Chief Engineers, Combustion Engineers, Electrical Engineers, Rolling Mill Superintendents, Master Mechanics and the Executives of the Iron and Steel Industry. The contents of the transactions are as follows:

The Conversion of Alternating Current to Direct Current—By G. H. Finks

General Phases of Pyrometry and Temperature Control in the Steel Industry—by O. Brewer.

The Motor That Corrects Power Factor—By H. Weischel.

Steel Mill Electrical Machinery and the Insulation Problem—By C. E. Skinner

Introduction: Ball and Roller Bearings—By D. M. Petty, Chairman Special Bearings Committee.

Application of Taper Roller Bearings—By T. V. Buckwalter.

Application of Anti-Friction Bearings—By F. W. Gurney.

Mounting and Maintenance of Roller Bearings on Electric Motors—By D. E. Batesole

Ball Bearing Applications and Maintenance—By H. R. Reynolds.

Application of Anti-Friction Bearings—By H. E. Brunner.

Selection, Installation and Operation of Anti-Friction Bearings—By J. T. R. Bell

Mounting and Maintenance of Roller Bearings in Electric Motors—By U. B. Wachtler.

Design and Application of Ball Bearings—By T. D. Crow.

Discussion on Ball and Roller Bearings—By Membership.

Control of Pressure Gas Producers—By W. P. Chandler, Jr.

Measurement of Input and Output in Boiler Rooms—By J. M. Spitzglass

The Prevention of Scale Formation by Boiler Water Conditioning—By R. E. Hall, Carl Fischer and George W. Smith.

The Chapman Stein Recuperator—By William C. Buell, Jr.

Some Applications of Oxygen to Ferrous Metallurgy—By F. W. Davis

The Ljungstrom Air Preheater—By B. G. Brolinson.

Mechanical and Electrical Analysis of 40" Blooming Mill Screwdown—By F. D. Egan

Electrically Driven Reversing Mills—By J. D. Wright, R. W. Davis and O. H. Needham.

Engine vs. Motor Drive for Reversing Blooming Mill—By C. H. Hunt

Discussion in Connection With Heating Furnaces By A. F. Mitchell.

Developments in Electric Maintenance Shop Practice—By A. C. Cummins

Power in the Iron and Steel Industry—By Barton R. Shover.

The Steel Industry and the Electric Utilities—By Merrill Skinner and F. D. Mahoney.

The Slagging Producer in Steel Works—By K. Huessener.

Crane Hoist Travel Limit Devices—By Walter Greenwood.

Combustion Control—By E. G. Bailey

Electric Furnace Installation—By Roy S. Sawdey.

Report of Electric Furnace Committee for 1924 By Geo. H. Schaeffer, Chairman.

Electric Melting Furnaces—By J. A. Seede

Medium Temperature Furnace Installations—By C. F. Cone.

Medium and Low Temperature Applications—By E. A. Hurme.

Electric Heating With Special References to Central Stations—By E. D. Sibley

Adjustable Speed Drives for Rolling Mills—By L. A. Umansky.

Electric Mining Equipment, Its Selection, Care and Operation—By A. F. Elliott

Direct Current Hoist and Trolley Control for Ore Bridges—By N. L. Mortensen

Electric Industrial Locomotives—By Frank E. Fisher.

STATEMENT OF OWNERSHIP, MANAGEMENT, ETC., OF

IRON AND STEEL ENGINEER

(Required by Act of Congress of August 24, 1912)

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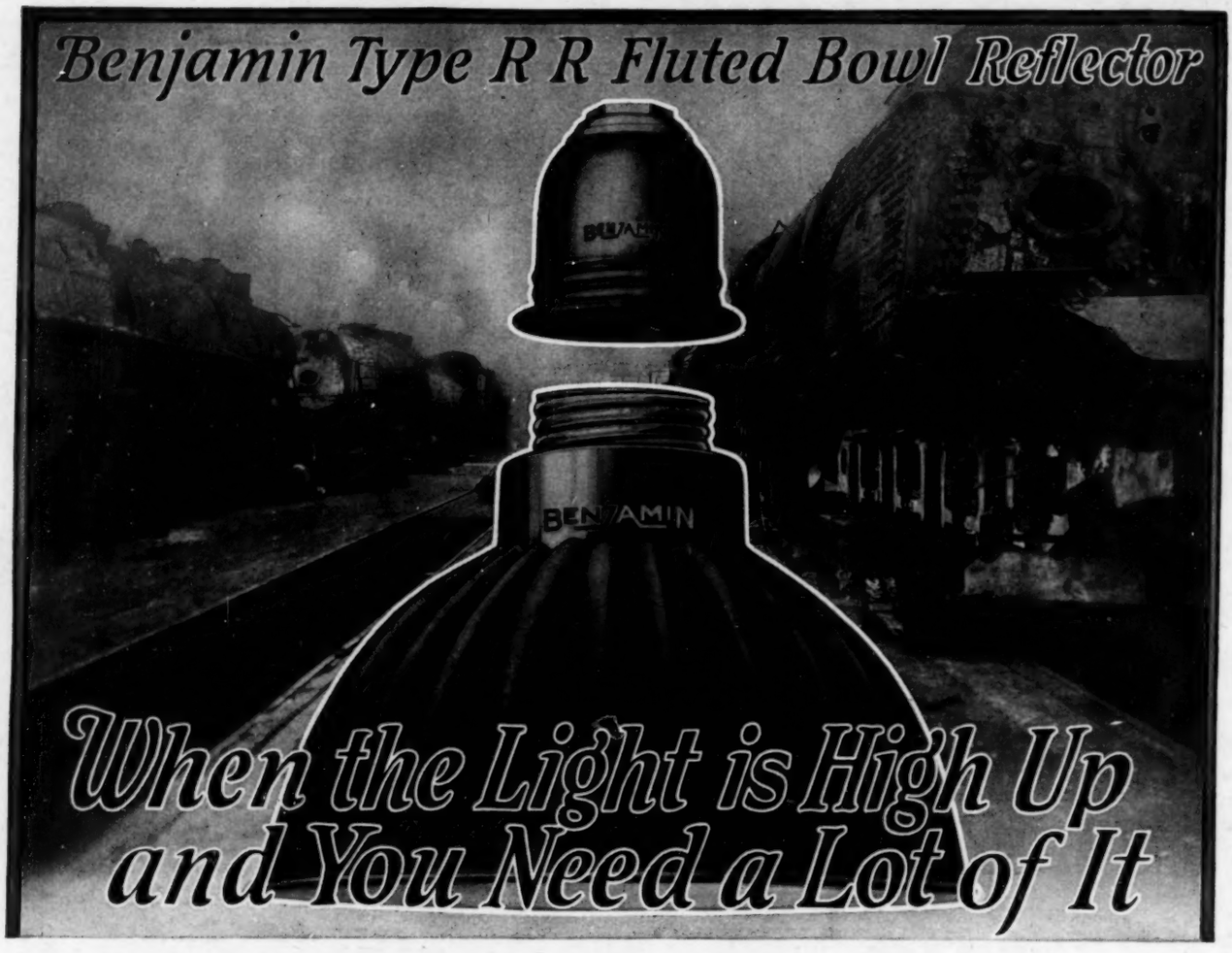
JOHN F. KELLY, Editor and Business Mgr.

Sworn to and subscribed before me this 23rd day of March, 1926.
JOHN G. HOSICK, Notary Public.
(My commission expires March 7, 1929.)

ADVERTISING PAGES REMOVED



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